

Description

This invention relates to a tube production machine including a welding management apparatus of the type defined in the preamble of claim 1.

BACKGROUND OF THE INVENTION

Tube production machines have been employed to produce a metal tube member by forming a workpiece fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other, providing an upsetting pressure to butt the opposite side surfaces of the workpiece at a jointing point, and supplying high frequency power to the workpiece to weld the opposite side surfaces at a welding point. It is the conventional practice to adjust the intensity of the welding heat generated at and near the jointing point by controlling the high frequency power to the workpiece based upon various tube producing conditions that are sensed during the operation of the tube production machine. However, the welding heat intensity is dependent upon a great number of tube producing conditions. It is very difficult, if not impossible, to adjust the welding heat intensity based upon all of the tube producing conditions.

From FR-A-2 575 686 there is known a tube production machine in which the metal strip is formed into a tubular member by a pair of upsetting rollers and its opposite edges are butted against each other. A high frequency current is passed via a contactor to the edges in association with a laser beam so that the edges are heated by the high frequency current and irradiated by the laser beam to be uniformly melted through the entire range of strip thickness. Thus uniformity of melting of the edges is achieved by using the laser beam which is controlled with the aid of a laser beam profile controller in such a manner that it irradiates a range of over 30% and below 80% of the strip thickness of the butted edges. In the control use is also made of a video camera which produces an optical image of the butted edges in a position anterior of the welded point. The camera feeds a video signal to a video analyser which calculates therefrom a melt width of each corner of the edges anterior of the welded point and feeds control data to a process controller. The video signal used in the prior art tube production machine is not converted into an electric signal which is indicative of an intensity of welding heat generated at the welding point or used for defining fuzzy sets which in turn are used to infer a cause of faulty welding and correct the supply of high frequency power on the basis thereof.

SUMMARY OF THE INVENTION

It is a main object of the invention to provide a tube production machine which can achieve excellent welding heat control with ease.

Another object of the invention is to provide a tube production machine which can infer a cause of defective welding.

There is provided, in accordance with one aspect of the invention, a tube production machine including first means for forming a workpiece fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point; third means for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor for converting the video signal into a luminance distribution pattern, a control unit responsive to the luminance distribution pattern for controlling the third means to adjust the high frequency power and sensor means sensitive to at least one of the tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit includes means responsive to the first electric signal for controlling the third means to adjust the high frequency power, means for storing membership functions defining each of first fuzzy sets provided for the welding heat indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets provided for the tube producing condition indicated by the second electric signal, means for detecting one of the first fuzzy sets in which the welding heat intensity indicated by the first electric signal is classified, means for detecting one of the second fuzzy sets in which the tube producing condition indicated by the second electric signal is classified, means for inferring a cause of defective welding as a function of the selected fuzzy sets and means for outputting the inferred cause.

From a second aspect of the invention there is provided a tube production machine including first means for forming a workpiece fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point; third means for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor for converting the video signal into a luminance distribution pattern, a control unit responsive to the luminance distribution pattern for controlling the third means to adjust the high frequency power and sensor means sensitive to at least one of the tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit includes means responsive to the first electric signal for controlling the third means to adjust the high frequency power, means for storing membership functions defining each of first fuzzy sets provided for the welding heat indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets provided for the tube producing condition indicated by the second electric signal, means for detecting one of the first fuzzy sets in which the welding heat intensity indicated by the first electric signal is classified, means for detecting one of the second fuzzy sets in which the tube producing condition indicated by the second electric signal is classified, means for storing a fuzzy rule specifying degrees of possibility of cause of a defective welding condition as a function of first and second fuzzy sets, and means for calculating a grade from the fuzzy rule based upon the selected fuzzy sets, the means for controlling the third means thereby adjusting the high frequency power based upon the calculated grade.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be described in greater detail by reference to the following description taken in connection with the accompanying drawings, in which:

- Fig. 1 is a schematic block diagram showing one embodiment of a tube production machine according to the invention;
- Fig. 2 is a fragmentary perspective view showing a welding section included in the tube production machine according to the invention;
- Fig. 3 is a fragmentary plan view showing a visual field of a camera used in a welding management apparatus forming part of the invention;
- Figs. 4A to 4D are fragmentary plan views showing four different welding heat conditions which may appear in the visual field of the camera;
- Fig. 5 is a schematic block diagram showing the detailed arrangement of the control unit used in the welding management apparatus forming part of the invention;
- Fig. 6 is a schematic diagram showing the image processor included in the welding management apparatus forming part of the invention;
- Fig. 7 is a diagram showing a luminance distribution pattern produced in the image processor;
- Figs. 8A and 8B are fragmentary plan views showing two defective welding conditions which may appear in the visual field of the camera;
- Fig. 9 is a diagram showing aperture forming steps which may occur with the lapse of time when the workpiece is made of iron;
- Fig. 10 is a fragmentary plan view showing a visual field of the camera used in the welding management apparatus for the workpiece made of iron;
- Fig. 11 is a diagram showing a luminance distribution pattern produced in the image processor when the workpiece is made of iron; and
- Fig. 12 is a fragmentary perspective view showing another type of welding section included in the tube production machine according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

With reference to the drawings, and in particular to Fig. 1, there is shown a schematic diagram of a welding management apparatus which forms part of the invention.

Although the welding management apparatus will be described in connection with a tube production machine employing a high frequency induction welding unit, it is to be understood that the invention is also applicable to other types of tube production machine. The tube production machine, generally designated by the numeral 10, employs a pair of forming rollers 11a and 11b, a heating coil 12, and a pair of squeeze rollers 13a and 13b to produce an elongated tube from a metal strip. In practice, the forming rollers are arranged in a number of stages to form a workpiece 1 fed from a roll of metal strip in a tubular formation. The squeeze rollers 13a and 13b are positioned on the opposite sides of the workpiece 1 and they provide an upsetting pressure to joint the opposite side surfaces of the workpiece 1 at a jointing point 1a just upstream of a point intermediate between the squeeze rollers 13a and 13b. The heating coil 12 is positioned to surround the workpiece 1 at a position upstream of the jointing point. The heating coil 12 is supplied with a high frequency power to produce a highly concentrated, rapidly alternating magnetic field so as to induce an electric potential in the workpiece 1. This electric potential causes heating because of $I^2 \cdot R$ losses at a welding point just downstream of the jointing point 1a where the opposite side surfaces 1b and 1c of the workpiece 1 are welded, as best shown in Fig. 2. The V-shaped gap, which is defined near the jointing point 1a by the opposite side surfaces 1b and 1c of the workpiece 1, is referred to as a V throat.

An electric motor 14 is powered from a source 15 of power to drive at least one of the forming rollers 11a and 11b. The speed of travel of the workpiece 1, this being determined by the level of the power to the electric motor 14, is determined from calculations performed in a motor control circuit 16, these calculations being based upon sensed conditions including the speed of the electric motor 14, the power applied to the electric motor 14, and a target value set for the power to the electric motor 14. Thus, a motor speed sensor 17, a power sensor 18 and a power setting device 19 are connected to the motor control circuit 16. The motor speed sensor 17 is provided at a position for sensing the speed of rotation of the electric motor 14 and it produces an electric signal indicative of the sensed motor speed. The power sensor 18 is placed at a position for sensing the power supplied to the electric motor 14 and it produces an electric signal indicative of the sensed power level. The power setting device 19 is used to manually set a target value for the power to the electric motor 14. The motor control circuit 16 controls the power to the electric motor 14 to the target value so as to maintain the motor speed at a desired value.

The heating coil 12 is powered from a high frequency power source 20 through a power control circuit 21. The welding heat under which the workpiece 1 is welded at the welding point, this being determined by the level of the power applied to the heating coil 12, is determined from calculations performed in a high frequency output control circuit 22, these calculations being made basically based upon the level of the power applied to the heating coil 12 and a target value set for the power to the heating coil 12. Thus, a power sensor 24 and a power setting device 25 are connected to the high frequency output control circuit 22. The power sensor 24 is provided at a position for sensing the level of the power supplied to the heating coil 12 and it produces a signal indicative of the sensed power level. The power setting device 25 is used to manually set a target value for the power to the heating coil 12. The high frequency output control circuit 22 produces a control signal, causing the power control circuit 21 to maintain the power to the heating coil 12 at the target value.

The high frequency output control circuit 22 also responds to correction signals ΔP , $\Delta \theta$ and ΔM fed thereto from a control unit 30 by controlling the power control circuit 21 to adjust the power to the heating coil 12 in a direction providing an optimum welding heat. The values of these correction signals are determined from calculations performed by a digital computer included in the control unit 30, these calculations being based upon various conditions that are sensed during the operation of the tube production machine. These sensed tube producing conditions include workpiece thickness T, workpiece width W, workpiece feed speed V, upsetting pressure P and welding heat θ . Thus, a workpiece thickness/width sensor 41, a workpiece feed speed sensor 42, an upsetting pressure sensor 43 and welding heat sensor 50 are connected to the control unit 30. The workpiece thickness/width sensor 41 is placed at a position just downstream of the roll of metal strip to measure the workpiece thickness M1 at one of the opposite edges of the workpiece 1, the workpiece thickness M2 at the other edge of the workpiece 1, and the width M3 of the workpiece 1 and it produces electric signals indicative of the sensed conditions M1, M2 and M3. The workpiece feed speed sensor 42 is associated with at least one of the feeding rollers 11a and 11b to measure the feed speed of the workpiece 1 and it produces an electric signal indicative of the sensed workpiece feed speed V. The upsetting pressure sensor 43 is associated with the squeeze rollers 13a and 13b to sense the upsetting pressure under which the workpiece 1 has its opposite side surfaces butted at the jointing point 1a between the squeeze rollers 13a and 13b and it produces an electric signal indicative of the sensed upsetting pressure P. The welding heat sensor 50 is provided at a position for sensing the welding heat inputted at a welding point of the workpiece 1 and it produces an electric signal θ indicative of the sensed welding heat. The welding heat sensor 50 is taken in the form of a camera

positioned above the workpiece 1. The camera 50, which may be of the type having an $M \times N$ array of CCD elements, is directed to have a visual field VF including the jointing and welding points, as shown in Fig. 3.

Figs. 4A to 4C show different welding conditions which may appear in the visual field of the camera 50. Fig. 4A shows a first welding condition where the opposite side surfaces 1b and 1c of the workpiece 1 are connected at the jointing point 1a. The first welding condition results from an insufficient welding heat. Fig. 4B shows a second welding condition where the opposite side surfaces 1b and 1c are connected at a point 2a upstream of the jointing point 1a by melted metal 2. An arc occurs frequently at the point 2a. The second welding condition occurs when the welding heat is within an appropriate range. Fig. 4C shows a third welding condition where the opposite side surfaces 1b and 1c are connected at a point 2b upstream of the jointing point 1a by melted metal 2. An arc occurs frequently at the point 2b. The distance between the points 1a and 2b, that is, the length of the melted metal 2, is greater than the distance between the points 1a and 2a. The third welding condition occurs at a welding heat greater than provided for the second welding condition. Fig. 4D shows a fourth welding condition where the opposite side surfaces 1b and 1c are connected at a point 2c upstream of the jointing point 1a by melted metal 2. The melted metal 2 moves violently between the points 1a and 2c and it cannot cover the whole area between the points 1a and 2c to form an aperture 3 behind the melted metal 2. An arc occurs frequently at the point 2c. The fourth welding condition results from an excessive welding heat.

The image formed on the CCD elements is scanned in a series of raster scan lines and converted into a video signal for application to the image processing unit 51. It is to be understood that the image formed on the CCD elements has synthetical information on which various welding conditions are reflected. The image processing unit 51 receives a video signal from the camera 50 and digitally stores the inputted image. The stored image A is represented by an $M \times N$ array of pixels. Each pixel $A(x,y)$ is assigned a value representation of its intensity. The image processing unit 51 scans the stored image A in a series of raster scan lines to convert it into a black/white image B represented by an array of pixels. Each pixel $B(x,y)$ has a value of 0 or 1. $B(x,y) = 0$ represents a white pixel, while $B(x,y) = 1$ represents a black pixel. In order to avoid the influence of the vapor and other disturbances near the jointing point 1a, the image processing unit 51 may be arranged to differentiate the signal obtained when the stored image A is scanned in a series of raster scan lines and to convert the differentiated signal into the black/white image B. The image processing unit 51 counts the number $\theta 1$ of white pixels of the stored image B and produces an electric signal θ corresponding to the counted white pixel number $\theta 1$. The electric signal θ represents the white area of the stored image B and, thus, the intensity of the welding heat. The image processing unit 51 may be arranged to produce the electric signal θ by counting the number $\theta 2$ of white pixels arranged to form a longitudinal center line on the stored image.

The control unit 30 also receives information as to whether or not the welded tube is defective. For this purpose, an eddy current crack detector 44 and an ultrasonic flaw detector 45 are positioned downstream of the squeeze rollers 13a and 13b. Each of the detectors 44 and 45 produces a defective tube indication signal when a welded tube defect is detected. A key board 31 is used to input various setting values into the control unit 30. The control unit 30 produces a command signal to the control circuit 22. The control unit 30 also makes a fuzzy inference of the cause of the defective welding condition and outputs the inferred cause through a CRT 32, a plotter 33 and a printer 34. A marker 35 is provided for marking a mark on the welded tube 1 on command from the control unit 30, for example, when a defective welding condition occurs.

Referring to Fig. 5, the control unit 30 has various monitor blocks 301, 302, 303 and 304. The first monitor block 301 is connected to the workpiece thickness/width sensor 41 and it monitors the workpiece conditions M including the workpiece thicknesses $M1$ and $M2$, the workpiece width $M3$ and the like. The second monitor block 302 monitors the tube forming conditions F including the edge height $F1$, the humidity $F2$, the oxygen concentration $F3$ and the like. The third monitor block 303 monitors the white pixel numbers $\theta 1$ and $\theta 2$ representing the welding heat intensity θ obtained through the camera 50. The fourth monitor block 304 monitors the welding machine conditions R including the workpiece feeding speed $R1$, the squeeze roller distance $R2$, the upsetting pressure $R3$ and the like. The monitored conditions are transferred from these monitor blocks to a fuzzy inference block 307. The control unit 30 also includes calculation blocks 305 and 306. The first calculation block 305 receives the measured thickness values $M1$ and $M2$ from the first monitor block 31 and it calculates a deviation ΔM of the average value of the measured workpiece thickness values $(M1 + M2)/2$ with respect to a target value M_s set for the workpiece thickness as $\Delta M = (M1 + M2)/2 - M_s$. The calculated deviation ΔM is transferred from the first calculation block 305 to the fuzzy inference section 307 and also to the high frequency output control circuit 22. The second calculation block 306 receives the monitored welding heat condition θ from the third monitor block 303 and it calculates a deviation $\Delta \theta$ of the monitored welding heat condition θ with respect to a target value

0s set for an optimum welding heat condition. The calculated deviation $\Delta\theta$ is transferred from the second calculation block 306 to the fuzzy inference section 307 and also to the high frequency output control circuit 22. The fuzzy inference section 307 includes a membership function generator section 308 and an inference section 309. The membership function generator section 308 stores and produces membership functions for the elements of each of fuzzy sets classified for each of the monitored conditions M1, M2, M3, ... ΔM , F1, F2, F3 ..., $\theta 1$, $\theta 2$, ... $\Delta\theta$, R1, R2, R3, ... The membership functions use grades ranging from 0 to 1 to define the respective elements included in the fuzzy set. The membership function generator 308 specifies one of the fuzzy sets in which the sensed value for one of the monitored conditions is classified. For example, the fuzzy sets may be PB (positive big), ZE (zero) and NB (negative big). The fuzzy set ZE corresponds to a range where the sensed value is appropriate for the monitored condition. The fuzzy set PB corresponds to a range where the sensed value is excessive for the monitored condition. The fuzzy set NB corresponds to a range where the sensed value is insufficient for the monitored condition. The grade indicates the extent to which the sensed value may be considered to have the characteristic specified for the fuzzy set. The inference section 307 utilizes the fuzzy set specified for the monitored conditions to make a fuzzy inference of the cause of defective welding. For this purpose, the control unit 30 includes a computer memory for storing fuzzy rules each of which specifies the degree of the possibility of the cause of a defective welding condition. The fuzzy rules may be obtained experimentally or derived empirically. One example of a fuzzy rule suitable for use with the fuzzy inference section 307 is shown in Table 1.

TABLE 1

PARAMETER A	PARAMETER B	INFERENCE				
(*)	(#)	POSSIBILITY OF WELDING HEAT DEFECT				
OUTPUT POWER	PIXEL NUMBER	GREAT	←→			SMALL
* = PB	# = PB	⑤	4	3	2	1
	# = ZE	5	④	3	2	1
	# = NB	5	4	③	2	1
* = ZE	# = PB	5	④	3	2	1
	# = ZE	5	4	③	2	1
	# = NB	5	4	3	②	1
* = NB	# = PB	5	4	③	2	1
	# = ZE	5	4	3	②	1
	# = NB	5	4	3	2	①

If the value sensed for the output power R1 is classified in the fuzzy set PB and the value sensed for the white pixel number $\theta 1$ is classified in the fuzzy set PB, then the possibility that the defective welding condition may be caused by defective welding heat is very great (grade 5). Alternatively, if the value sensed for the output power R1 is classified in the fuzzy set NB and the value sensed for the white pixel number $\theta 1$ is classified in the fuzzy set NB, then the possibility that the defective welding condition may be caused by

defective welding heat is very small (grade 1). The inferred cause of the defective welding condition is outputted through the CRT 32, the plotter 33 and/or the printer 34. The fuzzy inference section 307 also produces a correction signal ΔP to the high frequency output control circuit 22 which thereby controls the power control circuit 21 in a direction bringing the welding heat to an appropriate value. The inference section 307 calculates an appropriate value for the correction signal ΔP based upon the inferred cause. The control unit 30 may be arranged to produce a correction signal ΔP having a value corresponding to a deviation of the sensed pixel number $\theta 1$ or $\theta 2$ with respect to a predetermined reference value. It is to be noted that the pixel number $\theta 1$ or $\theta 2$ reflects the intensity of the welding heat generated at the welding point. In this case, the control circuit 22 controls the power control circuit 21 in a direction bring the pixel number to the reference value.

Referring to Fig. 6, there is shown a modified form of the image processing unit 51. In this modification, the image processing unit 51 includes an analog-to-digital converter 52 which receives the video signal from the camera 50 and converts it into digital form having 128 (0 to 127) tones for application to a first image memory 53 which digitally stores an image of the visual field represented by an $M \times N$ array of picture elements or pixels. Each pixel is assigned a value representative of its intensity (darkness). The stored image is scanned in a series of raster scan lines to convert it into a luminance (gray histogram) pattern. Fig. 7 shows one example of such a luminance pattern obtained for the third welding condition described in connection with Fig. 4C. The area surrounded by the lines P1 has the highest luminance level and corresponds to the melted metal 2. The area surrounded by the lines P2 corresponds to the workpiece portion adjacent to the melted metal 2.

The image processor 51 also includes a second image memory 54 which stores reference luminance patterns. The digital computer (CPU) 55 makes a determination as to whether or not the welding condition is appropriate by comparing the luminance pattern transferred thereto from the first image memory with the reference image patterns successively transferred thereinto from the second image memory 54. For this purpose, the digital computer 55 may be arranged to compare the area surrounded by the lines P1 with the corresponding area of each of the reference luminance patterns. The area surrounded by the lines P1 corresponds to the area of the melted metal 2 and it corresponds to the intensity of the welding heat. Alternatively, the digital computer 55 may be arranged to compare the longitudinal length of the area surrounded by the lines P1 with the corresponding length of each of the reference luminance patterns. The longitudinal length of the area surrounded by the lines P1 corresponds to the length of the melted metal 2 and it corresponds to the intensity of the welding heat. The digital computer 55 produces a decision signal indicative of the result of the comparison made in the image processing unit 51. The decision signal is fed from the image processing unit 51 to the control unit 30.

The high frequency output control circuit 22 includes a signal converter circuit 221, a signal control circuit 222, a power setting circuit 223 and a summing circuit 224. The signal converter circuit 221 receives the correction signal ΔP from the control unit 30 and converts it into an corresponding analog form for application to the signal control circuit 222. The signal control circuit 222 converts the analog signal into a power control signal. The control signal is supplied to the summing circuit 224. The power setting circuit 223 receives the correction signals $\Delta \theta$ and ΔM and produces a reference power signal to the summing circuit 224. The summing circuit 224 produces a control signal corresponding to a difference of the power control signal fed thereto from the signal control circuit 221 from the reference power signal fed thereto from the power setting circuit 223. The control signal is fed from the summing circuit 224 to cause the power control circuit 21 to control the high frequency power supplied from the power source 15 to the heating coil 12 in a direction providing an appropriate welding heat.

Figs. 8A and 8B show defective welding conditions which may appear in the visual field of the camera 50. Fig. 8A shows a defective welding condition where the jointing point 1a of the workpiece 1 is deviated upward from the center line 0-0 extending through the center between the squeeze rollers 13a and 13b. Fig. 8B shows another defective welding condition where the jointing point 1a of the workpiece 1 is deviated from the center line. These defective welding conditions result from the workpiece 1 being twisted to the left or right. The control unit 30 may be arranged to recognize the deviation of the jointing point 1a of the workpiece 1 with respect to the center line 0-0 based upon the luminance pattern produced in the image processing unit 51 and to produce a control signal causing an appropriate device to adjust the forming rollers 11a and 11b in a direction zeroing the deviation.

If the workpiece 1 is made of iron, an aperture 3 will be formed near the welding point. Fig. 9 shows aperture forming steps. At time T1, melted metal 2 appears at a position just upstream of the jointing point 1a. At time T2, a magnetic force is applied to push the melted metal 2 out to form an aperture 3. The aperture 3 becomes bigger at time T3. At time T4, the aperture 3 grows to its maximum extent. At time T5, the aperture 3 is filled up with a weld bead 4. These stages are repeated to produce an elongate tubular

member. The welding condition may be judged by using the camera 50 to monitor the size and position of the aperture 3. For this purpose, the camera 50 is directed to have a visual field VF including the jointing and welding points, as shown in Fig. 10. Fig. 11 shows the luminance pattern obtained in the image processor 51. The hatched area indicates the aperture 3. The size and/or position of the hatched area is used to control the welding heat generated at the welding point.

The invention is applicable to another type of welding machine as shown in Fig. 10. The welding machine includes a pair of contacts 5a and 5b placed in contact with the workpiece 1 on the opposite sides of a line along which welding is required. The contacts 5a and 5b are supplied with a high frequency power to produce an electric potential in the workpiece 1. This electric potential causes heating because of $I^2 \cdot R$ losses at the jointing point 1a where the opposite side surfaces 1b and 1c of the workpiece 1 are welded.

Claims

1. A tube production machine including first means (11a, 11b) for forming a workpiece (1) fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means (13a, 13b) for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point (1a); third means (12) for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera (50) positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor (51) for converting the video signal into a luminance distribution pattern, a control unit (22, 30) responsive to the luminance distribution pattern for controlling the third means (12) to adjust the high frequency power, and sensor means (41, 42, 43) sensitive to at least one of the tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means (55) for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit (22, 30) includes means (22) responsive to the first electric signal for controlling the third means (12) to adjust the high frequency power, means (308) for storing membership functions defining each of first fuzzy sets provided for the welding heat intensity indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets provided for the tube producing condition indicated by the second electric signal, means for detecting one of the first fuzzy sets in which the welding heat intensity indicated by the first signal is classified, means for detecting one of the second fuzzy sets in which the tube producing condition indicated by the second electric signal is classified, and means (309) for inferring a cause of defective welding as a function of the selected fuzzy sets and for outputting the inferred cause.
2. The tube production machine as claimed in claim 1, wherein the image processor (51) includes means (54) for storing at least one reference luminance distribution pattern, and means (55) for comparing the luminance distribution pattern with the reference luminance distribution pattern to produce the first electric signal.
3. A tube production machine including first means (11a, 11b) for forming a workpiece (1) fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means (13a, 13b) for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point (1a); third means (12) for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera (50) positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor (51) for converting the video signal into a luminance distribution pattern, a control unit (22, 30) responsive to the luminance distribution pattern for controlling the third means (12) to adjust the high frequency power, and sensor means (41, 42, 43) sensitive to at least one of tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means (55) for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit (22, 30) includes means (22) responsive to the first electric signal for controlling the third means (12) to adjust the high frequency power, means (308) for storing membership functions defining each of first fuzzy sets provided for the welding heat intensity indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets



member. The welding condition may be judged by using the camera 50 to monitor the size and position of the aperture 3. For this purpose, the camera 50 is directed to have a visual field VF including the jointing and welding points, as shown in Fig. 10. Fig. 11 shows the luminance pattern obtained in the image processor 51. The hatched area indicates the aperture 3. The size and/or position of the hatched area is used to control the welding heat generated at the welding point.

The invention is applicable to another type of welding machine as shown in Fig. 10. The welding machine includes a pair of contacts 5a and 5b placed in contact with the workpiece 1 on the opposite sides of a line along which welding is required. The contacts 5a and 5b are supplied with a high frequency power to produce an electric potential in the workpiece 1. This electric potential causes heating because of $I^2 \cdot R$ losses at the jointing point 1a where the opposite side surfaces 1b and 1c of the workpiece 1 are welded.

Claims

1. A tube production machine including first means (11a, 11b) for forming a workpiece (1) fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means (13a, 13b) for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point (1a); third means (12) for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera (50) positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor (51) for converting the video signal into a luminance distribution pattern, a control unit (22, 30) responsive to the luminance distribution pattern for controlling the third means (12) to adjust the high frequency power, and sensor means (41, 42, 43) sensitive to at least one of the tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means (55) for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit (22, 30) includes means (22) responsive to the first electric signal for controlling the third means (12) to adjust the high frequency power, means (308) for storing membership functions defining each of first fuzzy sets provided for the welding heat intensity indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets provided for the tube producing condition indicated by the second electric signal, means for detecting one of the first fuzzy sets in which the welding heat intensity indicated by the first signal is classified, means for detecting one of the second fuzzy sets in which the tube producing condition indicated by the second electric signal is classified, and means (309) for inferring a cause of defective welding as a function of the selected fuzzy sets and for outputting the inferred cause.
2. The tube production machine as claimed in claim 1, wherein the image processor (51) includes means (54) for storing at least one reference luminance distribution pattern, and means (55) for comparing the luminance distribution pattern with the reference luminance distribution pattern to produce the first electric signal.
3. A tube production machine including first means (11a, 11b) for forming a workpiece (1) fed from a roll of metal strip into a tubular formation having side surfaces opposite to each other; second means (13a, 13b) for providing an upsetting pressure to joint the opposite side surfaces of the workpiece at a jointing point (1a); third means (12) for supplying a high frequency power to the workpiece to weld the opposite side surfaces at a welding point so as to produce a metal tube member; and a welding management apparatus including a camera (50) positioned to have a visual field including the jointing and welding points for producing a video signal indicative of an image of the visual field, an image processor (51) for converting the video signal into a luminance distribution pattern, a control unit (22, 30) responsive to the luminance distribution pattern for controlling the third means (12) to adjust the high frequency power, and sensor means (41, 42, 43) sensitive to at least one of tube producing conditions for producing a second electric signal indicative of a sensed tube producing condition, characterized in that the image processor includes means (55) for converting the luminance distribution pattern into a first electric signal indicative of an intensity of welding heat generated at the welding point; and in that the control unit (22, 30) includes means (22) responsive to the first electric signal for controlling the third means (12) to adjust the high frequency power, means (308) for storing membership functions defining each of first fuzzy sets provided for the welding heat intensity indicated by the first electric signal, means for storing membership functions defining each of second fuzzy sets



provided for the tube producing condition indicated by the second electric signal, means for detecting one of the first fuzzy sets in which the welding heat intensity indicated by the first signal is classified, means for detecting one of the second fuzzy sets in which the tube producing condition indicated by the second electric signal is classified, means for storing a fuzzy rule specifying degrees of possibility of cause of a defective welding condition as a function of first and second fuzzy sets, and means for calculating a grade from the fuzzy rule based upon the selected fuzzy sets, the means (22) for controlling the third means (12) thereby adjusting the high frequency power based upon the calculated grade.

4. The tube production machine as claimed in claim 3, wherein the image processor (51) includes means (54) for storing at least one reference luminance distribution pattern, and means (55) for comparing the luminance distribution pattern with the reference luminance distribution pattern to produce the first electric signal.

15 Patentansprüche

1. Eine Rohrherstellungsmaschine mit ersten Mitteln (11a, 11b) zum Formen eines Werkstückes (1), das von einer Metallstreifenrolle zugeführt wird, in eine rohrförmige Form mit Seitenflächen, die einander gegenüberliegen; zweiten Mitteln (13a, 13b) zur Bereitstellung eines Stauchdruckes, um die gegenüberliegenden Seitenflächen des Werkstückes an dem Verbindungspunkt (1a) zu verbinden; dritten Mitteln (12) zum Zuführen einer Hochfrequenzenergie zu dem Werkstück, um die gegenüberliegenden Seitenflächen an einem Schweißpunkt zu schweißen und so ein Metallrohrelement herzustellen; und einem Schweißvorgangssteuerungsgerät mit einer Kamera (50), die so positioniert ist, daß sie einen Sichtbereich hat, der die Verbindungs- und Schweißpunkte einschließt, um ein Videosignal zu erzeugen, das indikativ für ein Bild des Sichtbereiches ist, einer Bildverarbeitungseinrichtung (51) zum Umwandeln des Videosignals in ein Helligkeitsverteilungsmuster, einer Steuerungseinheit (22, 30), die auf das Helligkeitsverteilungsmuster zur Steuerung des dritten Mittels (12) reagiert, um die Hochfrequenzenergie einzustellen, und Sensormitteln (41, 42, 43), die empfindlich auf mindestens einen der Rohrherstellungszustände sind, um ein zweites elektrisches Signal zu erzeugen, das indikativ für einen erfaßten Rohrherstellungszustand ist, dadurch gekennzeichnet, daß die Bildverarbeitungseinrichtung Mittel (55) aufweist, um das Helligkeitsverteilungsmuster in ein erstes elektrisches Signal umzuwandeln, das indikativ für eine Intensität der Schweißwärme ist, welche an dem Schweißpunkt erzeugt wird; und daß die Steuerungseinheit (22, 30) Mittel (22), die auf das erste elektrische Signal reagieren, um das dritte Mittel (12) zu steuern und die Hochfrequenzenergie einzustellen, Mittel (308) zur Speicherung von Zugehörigkeitsfunktionen, die jede von ersten Fuzzy-Mengen definieren, welche für die Schweißwärmeeintensität vorgesehen sind, die durch das erste elektrische Signal angezeigt wird, Mittel zur Speicherung von Zugehörigkeitsfunktionen, die jede von zweiten Fuzzy-Mengen definieren, die für den durch das zweite elektrische Signal angezeigten Rohrherstellungszustand vorgesehen sind, Mittel zur Erfassung von einer der ersten Fuzzy-Mengen, in denen die Schweißwärmeeintensität, welche durch das erste Signal angezeigt wird, klassifiziert ist, Mittel zur Erfassung von einer der zweiten Fuzzy-Mengen, in die der durch das zweite elektrische Signal angezeigte Rohrherstellungszustand klassifiziert ist, und Mittel (309) zur Herleitung einer Ursache für ein fehlerhaftes Schweißen als eine Funktion der gewählten Fuzzy-Mengen und zum Ausgeben der gefolgerten Ursache, umfaßt.
2. Die Rohrherstellungsmaschine wie in Anspruch 1 beansprucht, worin die Bildverarbeitungseinrichtung (51) Mittel (54) zum Speichern von mindestens einem Bezugshelligkeitsverteilungsmuster und Mittel (55) zum Vergleichen des Helligkeitsverteilungsmusters mit dem Bezugshelligkeitsverteilungsmuster, um das erste elektrische Signal zu erzeugen, aufweist.
3. Eine Rohrherstellungsmaschine mit ersten Mitteln (11a, 11b) zum Formen eines Werkstückes (1) welches von einer Metallstreifenrolle zugeführt wird, in eine rohrförmige Form mit einander gegenüberliegenden Seitenflächen; zweiten Mitteln (13a, 13b) zur Bereitstellung eines Stauchdruckes, um die gegenüberliegenden Seitenflächen des Werkstückes an einem Verbindungspunkt (1a) zu verbinden; dritten Mitteln (12) zum Zuführen einer Hochfrequenzenergie zu dem Werkstück, um die gegenüberliegenden Seitenflächen an einem Schweißpunkt zu schweißen und ein Metallrohrelement herzustellen; und einem Schweißvorgangssteuerungsgerät mit einer Kamera (50), die so positioniert ist, daß sie einen Sichtbereich hat, der die Verbindungs- und Schweißpunkte umfaßt, um ein Videosignal zu erzeugen, das indikativ für ein Bild des Sichtbereiches ist, einer Bildverarbeitungseinrichtung (51) zum



Umwandeln des Videosignals in ein Helligkeitsverteilungsmuster, einer Steuerungseinheit (22, 30), die auf das Helligkeitsverteilungsmuster reagiert, um die dritten Mittel (12) zu steuern und hierdurch die Hochfrequenzenergie einzustellen, und Sensormitteln (41, 42, 42), die empfindlich auf mindestens einen von Rohrherstellungszuständen sind, um ein zweites elektrisches Signal zu erzeugen, das indikativ für einen erfaßten Rohrherstellungszustand ist, dadurch gekennzeichnet, daß die Bildverarbeitungseinrichtung Mittel (55) aufweist, um das Helligkeitsverteilungsmuster in ein erstes elektrisches Signal umzuwandeln, das indikativ für eine Intensität der Schweißwärme ist, welche an dem Schweißpunkt erzeugt wird; und daß die Steuerungseinheit (22, 30) Mittel (22), die auf das erste elektrische Signal reagieren, um die dritten Mittel (12) zu steuern und so die Hochfrequenzenergie einzustellen, Mittel (308) zur Speicherung von Zugehörigkeitsfunktionen, die jede von ersten Fuzzy-Mengen definieren, welche für die durch das elektrische Signal angezeigte Schweißwärmeintensität vorgesehen sind, Mittel zur Speicherung von Zugehörigkeitsfunktionen, welche jede von zweiten Fuzzy-Mengen definieren, die für den durch das zweite elektrische Signal angezeigten Rohrherstellungszustand vorgesehen sind, Mittel zur Erfassung einer der ersten Fuzzy-Mengen, in denen die durch das erste Signal angezeigte Schweißwärmeintensität klassifiziert ist, Mittel zur Erfassung einer der zweiten Fuzzy-Mengen, in denen der durch das zweite elektrische Signal angezeigte Rohrherstellungszustand klassifiziert ist, Mittel zur Speicherung einer Fuzzy-Regel, die die Maße an Wahrscheinlichkeit einer Verursachung eines fehlerhaften Schweißzustands als eine Funktion von ersten und zweiten Fuzzy-Mengen speichert, und Mittel zur Berechnung einer Abstufung von der Fuzzy-Regel basierend auf den gewählten Fuzzy-Mengen, wobei die Mittel (22) zur Steuerung der dritten Mittel (12) hierdurch die Hochfrequenzenergie basierend auf der berechneten Abstufung einstellen, aufweist.

4. Die Rohrherstellungsmaschine wie in Anspruch 3 beansprucht, worin die Bildverarbeitungseinrichtung (51) Mittel (54) zur Speicherung von mindestens einem Bezugshelligkeitsverteilungsmuster und Mittel (55) zum Vergleichen des Helligkeitsverteilungsmuster mit dem Bezugshelligkeitsverteilungsmuster aufweist, um das erste elektrische Signal zu erzeugen.

Revendications

1. Machine de production de tube comprenant un premier dispositif (11a, 11b) pour former une pièce (1) alimentée à partir d'un rouleau de bande de métal en une formation tubulaire ayant des surfaces latérales opposées l'une à l'autre ; un second dispositif (13a, 13b) pour fournir une pression de déformation pour joindre les surfaces latérales opposées de la pièce en un point de jonction (1a) ; un troisième dispositif (12) pour fournir une puissance haute fréquence à la pièce pour souder les surfaces latérales opposées en un point de soudure afin de produire un élément de tube de métal ; et un appareil de commande pour soudage comprenant une caméra (50) positionnée pour avoir un champ visuel comprenant les points de jonction et de soudure pour produire un signal vidéo indicateur d'une image du champ visuel, un processeur d'image (51) pour convertir le signal vidéo en un modèle de distribution de luminance, une unité de commande (22, 30) sensible au modèle de distribution de luminance pour commander le troisième dispositif (12) pour régler la puissance haute fréquence, et un dispositif de capteur (41, 42, 43) sensible à au moins une des conditions de production de tube pour produire un second signal électrique indicateur d'une condition détectée de production de tube, caractérisée en ce que le processeur d'image comprend un dispositif (55) pour convertir le modèle de distribution de luminance en un premier signal électrique indicateur d'une intensité de chauffe soudante générée au point de soudure ; et en ce que l'unité de commande (22, 30) comprend un dispositif (22) sensible au premier signal électrique pour commander le troisième dispositif (12) pour régler la puissance haute fréquence, un dispositif (300) pour stocker des fonctions d'appartenance définissant chacun des premiers ensembles flous fournis pour l'intensité de chauffe soudante indiquée par le premier signal électrique, un dispositif pour stocker des fonctions d'appartenance définissant chacun des seconds ensembles flous fournis pour la condition de production de tube indiquée par le second signal électrique, un dispositif pour détecter un des premiers ensembles flous dans lequel l'intensité de chauffe soudante indiquée par le premier signal est classifiée, un dispositif pour détecter un des seconds ensembles flous dans lequel la condition de production de tube indiquée par le second signal électrique est classifiée, et un dispositif (309) pour inférer une cause d'un soudage défectueux comme une fonction des ensembles flous sélectionnés et pour fournir la cause inférée.
2. Machine de production de tube selon la revendication 1, dans laquelle le processeur d'image (51) comprend un dispositif (54) pour stocker au moins un modèle de distribution de luminance de



référence, et un dispositif (55) pour comparer le modèle de distribution de luminance avec le modèle de distribution de luminance de référence pour produire le premier signal électrique.

- 5 3. Machine de production de tube comprenant un premier dispositif (11a, 11b) pour former une pièce (1) alimentée à partir d'un rouleau de bande de métal en une formation tubulaire ayant des surfaces latérales opposées l'une à l'autre ; un second dispositif (13a, 13b) pour fournir une pression de déformation pour joindre les surfaces latérales opposées de la pièce en un point de jonction (1a) ; un troisième dispositif (12) pour fournir une puissance haute fréquence à la pièce pour souder les surfaces latérales opposées en un point de soudure afin de produire un élément de tube de métal ; et un
- 10 appareil de commande pour soudage comprenant une caméra (50) positionnée pour avoir un champ visuel comprenant les points de jonction et de soudure pour produire un signal vidéo indicateur d'une image du champ visuel, un processeur d'image (51) pour convertir le signal vidéo en un modèle de distribution de luminance, une unité de commande (22, 30) sensible au modèle de distribution de luminance pour commander le troisième dispositif (12) pour régler la puissance haute fréquence, et un
- 15 dispositif de capteur (41, 42, 43) sensible à au moins une des conditions de production de tube pour produire un second signal électrique indicateur d'une condition détectée de production de tube, caractérisée en ce que le processeur d'image comprend un dispositif (55) pour convertir le modèle de distribution de luminance en un premier signal électrique indicateur d'une intensité de chauffe soudante générée au point de soudure ; et en ce que l'unité de commande (22, 30) comprend un dispositif (22)
- 20 sensible au premier signal électrique pour commander le troisième dispositif (12) pour régler la puissance haute fréquence, un dispositif (308) pour stocker des fonctions d'appartenance définissant chacun des premiers ensembles flous fournis pour l'intensité de chauffe soudante indiquée par le premier signal électrique, un dispositif pour stocker des fonctions d'appartenance définissant chacun des seconds ensembles flous fournis pour la condition de production de tube indiquée par le second
- 25 signal électrique, un dispositif pour détecter un des premiers ensembles flous dans lequel l'intensité de chauffe soudante indiquée par le premier signal électrique est classifiée, un dispositif pour détecter un des seconds ensembles flous dans lequel la condition de production de tube indiquée par le second signal électrique est classifiée, un dispositif pour stocker une règle floue spécifiant des degrés de possibilité de cause d'une condition de soudage défectueux comme une fonction des premier et
- 30 second ensembles flous, et un dispositif pour calculer un grade à partir de la règle floue sur la base des ensembles flous sélectionnés, un dispositif (22) pour commander le troisième dispositif (12) ajustant ainsi la puissance haute fréquence sur la base du grade calculé.
- 35 4. Machine de production de tube selon la revendication 3, dans laquelle le processeur d'image (51) comprend un dispositif (54) pour stocker au moins un modèle de distribution de luminance de référence, et un dispositif (55) pour comparer le modèle de distribution de luminance avec le modèle de distribution de luminance de référence pour produire le premier signal électrique.
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