

METHOD FOR INDUCTION BEND FORMING A PRESSURE-RESISTANT PIPE HAVING A LARGE WALL THICKNESS AND A LARGE DIAMETER

[001] The invention relates to a method for induction bend forming a pressure-resistant pipe having a large wall thickness and a large diameter, in particular a pipe in a power plant and a pipeline with the features of the preamble of claim 1.

[002] For carrying liquid and gaseous media under pressure, steel pipes are required that have a large wall thickness in order to withstand the stresses. Such requirements apply, for example, to the transport of hot steam in power plants, where pipe bends are required in order to adapt the pipelines to the constructional circumstances or for transporting crude oil in pipelines over long distances, where flexible U-shaped expansion loops are used at regular intervals to compensate for thermally induced changes in length. To enable a large throughput, a large opening cross-section and correspondingly a large outer pipe diameter is required. The present method relates to pipes with typical nominal diameters greater than 300 mm and a diameter to wall thickness ratio of 10:1 to 100:1, typically 20:1 to 70:1.

[003] Such a method for induction bend forming has long been known, for example from DE 2513561 A1 and has been continually improved in order to produce dimensionally very stable pipe bends despite the enormous dimensions. Forming of such massive pipes can only be achieved by inductively heating a narrow annular zone to a forming temperature above 850°C. Structural changes occur in the material, which is usually fine-grained steel, in the heat-affected zone. In order to homogenize the structure after hot forming and thus improve the mechanical properties of the steel, the pipe bend is subsequently often heat-treated at a temperature of about

600°C. The straight pipe sections, which are connected before and after the pipe bend and are also referred to as tangents, are also influenced by the subsequent heat treatment. However, since they were not heated to a high temperature in the course of the forming process and their structure has, therefore, remained unchanged, the subsequent heat treatment has a negative effect on these sections; they embrittle. Thus, these sections must be separated, and the pipe bend produced by induction bend forming has to be welded to new tangents.

[004] This has disadvantages because of the high work effort, in particular when a plurality of pipe bends, even in different directions, are carried out successively on the same pipe piece, as made possible by the device described in DE 10 2010 020 360 A1. The simplification and acceleration of pipeline construction thus achieved by producing a three-dimensional pipe structure in only one operation is negated if the straight tangent pieces have to be replaced because a thermal post-treatment of the pipe formation necessary in order to achieve certain strength values. To avoid this, only the use of pipes of high-strength steels and/or of greater wall thickness is possible in order to retain the mechanically required minimum strength values for the overall structure after the heat treatment at the tangents. However, this approach is also disadvantageous because of considerably higher material prices.

[005] The problem addressed by the present invention is thus to improve the method of the aforementioned kind in such a way that negative influences of the forming process on the strength values of the material in the tangents adjoining the pipe bends are avoided.

[006] The invention solves this through the method with the features of claim 1.

[007] The solution approach according to the invention is based on subjecting the tangents before and after the bend to exactly the same heat treatment that the bend section of the pipe has to undergo during forming, i.e., to pass the tangents through the induction device at the same speed as the pipe section to be bent and to apply the same temperature in the induction device as well as the same cooling parameters thereafter. The difference in the pass-through of the tangents is therefore simply that the pipe is not clamped in the bending lock during the treatment of the tangent and therefore no counter-forces are in effect during the feed.

[008] Clamping only the rear end of the pipe without any further support makes it possible to operate independently of the clamping of the front end in the bending lock and furthermore allows the inductor to move freely in the direction of the rear end along the pipe wall unobstructed by support devices.

[009] The solution according to the invention provides for an exact adjustment of the movements of the feed unit and of the inductor, which is executed and monitored by a control unit. These steps are explained in more detail below with reference to the drawings. The figures show in detail:

[0010] Fig. 1 a schematic view of an induction pipe-bending device.

[0011] Figs. 2a - 2d the induction pipe-bending device in respective different positions during execution of the method; and

[0012] Figs. 3 and 4 each a flow chart, in which movement speeds are plotted against the path.

[0013] Fig. 1 shows an induction pipe-bending device 100 comprising a stationary machine bed 10 on which a holding device 11 for a pipe 1 is arranged. The holding device 11 grips the pipe 1 at its rear end and clamps it tightly. In addition, the holding device 11 can be moved in relation to the machine bed in the direction of a pipe center axis 2, which at the same time indicates the feed direction. The feed is carried out via a hydraulic unit 12.

[0014] An induction device comprises an annular inductor 20, which is positioned with its center in the region of the pipe center axis 2. According to the invention, a linear adjusting device 21 is provided in order to move the inductor 20 relative to the machine bed 10.

[0015] A bending arm 30 is pivotally supported at a vertical bending axis 32, wherein the distance of the bending axis 32 perpendicular to the pipe center axis 2 can be adjusted in order to set the desired bending radius. A bending lock 31 for gripping and clamping the pipe 1 is arranged on the bending arm 30.

[0016] Relatively close to the inductor 20 and the heat inflow zone is a cooling device 40, with which the surface temperature is cooled down, for example using water, as soon as the corresponding length section has emerged from the forming zone.

[0017] Sensors for capturing the path and speed of the pipe 1 as well as of the inductor ring 20 are provided for carrying out the method according to the invention, as well as control modules

in a control unit with which the paths and speed, as well as the connection and disconnection of the inductor unit, are brought into the correlations provided according to the invention.

[0018] Figs. 2a to 2d show various stages during the execution of the method. Fig. 3 shows the time points or phases t1 to t6 associated with the illustrations in Figs. 2a to 2d in a diagram in which the upper graph indicates the speed of the feed device or the longitudinal feed rate v_R of the pipe 1 against the path, and the lower graph the travel speed v_I of the inductor across the path. Positive speed values correspond to a movement in the feed direction; negative values indicate a counter-movement.

[0019] At the starting time shown in Fig. 2a, the front end of the pipe is pushed into the inductor ring 20, which is located at its actual starting position. In contrast to induction bend forming according to the prior art, the front pipe end, which also forms the front tangent 3 later on the formed pipe bend, is not yet secured in the bending lock 31.

[0020] The induction device 20 and the cooling device are switched on and the axial advance of the pipe 1 takes place in a first phase (see Fig. 3) with a constant pipe feed rate v_R . It is typically 3 mm - 200 mm per minute. As a result, the tangent 3 is heat-treated on the pipe in the same way as in the subsequent forming, however, without an actual forming taking place. This phase is designated as t1 in the time-speed diagram in Fig. 3. As can also be seen here, there is no travel speed v_I of the inductor 20; it is, therefore, stationary.

[0021] In order to begin the bending process, the bending lock 31 on the bending arm 30 must grip the pipe 1 and clamp it so that the forces, which lead to the bending, can be introduced. However, the approach of the bending lock 31 and the application of the clamping forces require a certain period of time. A relative movement between the bending lock 31 and the pipe 1 must be avoided during the approach. The bending arm 30 with its bending lock 31 cannot be moved parallel to the advance of the pipe 1 because the structural effort for such a longitudinal movement of the support for the bending arm 30 would be much too high and because the distance of the bending lock 31 from the heating zone on the inductor ring 20 would change.

[0022] Therefore, according to the invention, the relative movement between the pipe 1 and the bending lock 31 is to be neutralized in a short phase t_2 (see Fig. 3) by stopping the pipe feed, that is, the pipe feed rate $v_R = 0$, and simultaneously keeping the advance of the pipe 1 relative to the inductor 20 in that the latter is moved with a travel speed v_I opposite to the direction of advance and with the same magnitude of the speed v_R as the pipe feed. Inasmuch as a gradual, linear deceleration of the mechanical pipe feed is necessary, the backward movement of the inductor 20 begins at the same time, so that the relative speed is always constant, which can be seen in consistent distances of the two graphs for v_R and v_I in Fig. 3.

[0023] When the pipe 1 is at a standstill, the bending lock 31 can be moved in, as shown in Fig. 2b. During this time, the inductor 20 continues its counter-movement with a constant travel speed v_I . As soon as the bending lock 31 has clamped the pipe 1, the inductor speed v_I is returned to zero in phase t_3 and at the same time, the pipe feed rate v_R of the pipe 1 is increased linearly. The speed difference $\Delta v = v_R - v_I$ is always the same so that the throughput speed of each

differential length section of pipe 1 through the inductor 20 is the same and thus always the same energy from the inductor acts upon the pipe jacket. During the phase t3, the inductor 20 moves back into its starting position, which corresponds to the working position for the bending process.

[0024] If a pipe bend is to be produced, the initial point of the bend, which is present at the end of phase t3, can lie arbitrarily on the longitudinal axis 2 of pipe 1. On the other hand, the above-described operations at t1, t2, and t3 must be started with a precisely calculated approach so that a certain axial pipe position for the beginning of the bending process is reached when bending begins.

[0025] During the phase t4, the known induction bending process is carried out with a constant pipe feed rate v_R and a stationary inductor 20, as shown in Fig. 2c, to produce a pipe bend 4.

[0026] In order to subject a rear tangent 5 on the pipe 1 to the same heat treatment as the remaining length sections of pipe 1 after the completion of the pipe bend 4, the pipe 1 and the inductor 20 move in opposite directions to the above-described starting process.

[0027] Shortly before reaching the intended bend length, the pipe feed is gradually slowed down in phase t5 at the speed v_R and at the same time, the opposing movement of the inductor 20 starts at such a travel speed v_I that the relative movement between the pipe 1 and inductor 20 remains constant. As a result, the residence time of each length section of the pipe 1 also remains

constant in the migrating heat-affected zone. When the pipe 1 is at a standstill, the bending lock 31 can be opened. As a result, pipe 1 is now completely unobstructed by the bending arm 30.

[0028] To treat only a short end-side tangent 5 on the pipe 1, the inductor 20 can be moved simply into its end position facing the machine bed 10 in phase t6 with a constant travel speed v_I , see Fig. 2d. There, the inductor 20 is then stopped and the induction device is switched off. The non-heat-treated remaining piece of the pipe 1 is marked and separated immediately, but at the latest after the heat treatment of the pipe bend 3 thus produced with its end-side tangent sections 3, 4.

[0029] In order to obtain a longer tangent 5, in particular a tangent 5 followed directly by a further pipe bend, the method can be continued, as can be seen from the further flow chart according to Fig. 4. For this purpose, the longitudinal feed of the pipe 1 is gradually taken up in phase t7, in the same manner as in phase t3, and the inductor 20 is returned to its starting position. The heat treatment of the tangent 5 can then be continued in phase t8 at a constant pipe feed rate v_R as long as is necessary to obtain a sufficiently long, heat-treated tangent 5. The bending lock 31 is not involved in this phase. Phase t8 thus corresponds to phase t1.

Patent Claims:

1. Method for induction bend forming a pressure-resistant pipe (1) having a large wall thickness and a large diameter, in particular a pipe in a power plant and a pipeline,

with at least the following steps

- Supporting the unprocessed pipe (1) on a machine bed (10)
- Feeding the pipe (1) through an annular inductor (20) of an electrical induction unit with a pipe feed speed v_R ;
- Clamping the front pipe section (3) in a pipe lock (31), which is supported on a bending arm (30) that can pivot around a vertical axis of rotation (32) arranged on the side of the pipe (1).
- Supplying current to the induction device for heating a pipe section located within the inductor (20);
- Deflecting the bending arm (30) through a longitudinal advance of the pipe (1) until the pipe bend (4) is completed;

characterized in that,

- the pipe (1) is clamped with its rear end in a holding device (11), which is supported moveably in the direction of a longitudinal pipe axis (2);
- in that in a starting phase t_1 , a starting tangent (3) of the pipe (1) is heat-treated by pushing the initial tangent (3) through the inductor (20) without engagement of the bending lock (31);

- in that the pipe feed is stopped at a time t_2 at the end of the starting tangent (3) and the inductor (20) is moved along the pipe (1) counter to the direction of advance, while the bending lock (31) is closed on the pipe (1);
- in that a travel speed v_I of the inductor (20) is reduced to zero in order to initiate bending of the pipe (1) in a phase t_3 , and is moved into its bending position and at the same time the feed of the pipe (1) begins until the pipe feed rate v_R is reached;
- in that a pipe bend (4) is produced in a phase t_4 with a constant pipe feed rate v_R of the pipe (1),
- in that in a phase t_5 , the pipe feed rate v_R is reduced and the inductor (20) is accelerated counter to the feed direction, wherein the bending lock (31) is opened;
- in that in a phase t_6 , an end tangent (5) is heated by further advance of the inductor in the opposite direction.

2. A method as in claim 1, characterized in that the inductor (20) is moved into a starting position, which, viewed in the feed direction, is located before a bending position.

3. A method as in claim 2, characterized in that the inductor (20) is moved into its starting position from a rearward position, viewed in the feed direction, before the beginning of phase t_1 .

4. A method as in claim 2, characterized in that the inductor (20) is moved into its starting position during phase t_1 from a rearward position, viewed in the feed direction, wherein the pipe feed rate v_R is increased by the travel speed v_I of the inductor (20).

5. A method as in one of the claims 1 to 4, characterized in that the relative speed as the difference between the pipe feed rate v_R and the travel speed v_I of the inductor (20) is constant in phases t_1 to t_6 .