METHOD OF PROGRESSIVELY HEATING SHEET METAL AND AN
INDUCTION COIL FOR PERFORMING THE METHOD
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METHOD OF PROGRESSIVELY HEATING SHEET METAL AND AN INDUCTION COIL FOR PERFORMING THE METHOD

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The invention relates to a method of progressively heating ferritic sheet, more particularly in the form of strip, by induction.

The inductive heating of sheet and strip is known to call for the observance of special conditions when thin sheet or strip is being heated, and more particularly if it is only 0.5 mm. or less, say 0.10 to 0.35 mm., thick. The heating of sheet and strip may be necessary for various reasons. It is a treatment of outstanding impor-
tance in the production of tinned sheet or strip. When "strip" (which term shall hereinafter and in the claims hereof be understood to include sheet) has been galvanically tinned, the tin must be "flowed" on the strip. The temperatures required for this purpose are under 500° C, more particularly between 200 and 300° C. It is a matter of the greatest importance that prior to hardening the flowed tin should be precluded from making contact with any other object, as this would spoil the lustre of the finished tinned surface. The proposal to heat the strip inductively for flowing the tin dates from a very early stage in the development of the art. For this purpose the strip is taken through induc-
tion coils which heat the strip. Bearing in mind that the strip may be of a thickness only of between 0.10 and 0.35 mm., high frequency currents are exclusively used for this purpose. Since the strip travels through, the induction heater in the axial direction of the coils, the magnetic field passes through the strip in the direction of travel and induces an eddy current which flows around the perimeter of the strip (viewed in section). In view of the well-known formulae that govern the depth of penetration of the induced currents and in view of the thinness of the material the performance of the process calls for the application of frequencies in the order of 100,000 cycles per second and even more. Hence, valve oscillators have to be used for their production. If the velocity of travel of the strip during the heating process is very high these valve oscillators must have a rated output of 500 kw., and even more, to satisfy normal conditions of production. As known, considerable diffi-
culties are experienced in providing valves of this kind, and the plant is not easy to maintain and very liable to breakdown.

It has therefore also been proposed to work at lower frequencies, for instance at mains frequency or at me-
dium frequencies. However, to permit the temperature of the strip at these frequencies to be raised at all, the method of cross field heating must be employed. On both sides of the strip coils with magnetic cores are pro-
vided for ensuring that the magnetic field will extend across the strip. By applying this method it is possible to bring about an adequate heating effect in the strip. However, the disadvantage arises that the strip is at the same time subjected to considerable magnetic forces. An assembly of magnetic coils must therefore be pro-
vided on both sides of the strip in order to balance these magnetic forces as well as this may be possible. How-
ever, if the arrangement is not absolutely symmetrical in relation to the median axis of the strip, the latter will be attracted towards one of the coils and come into contact with it, spoiling the tinning on the strip. As a result of the difficulties and despite the fact that inductive heating is a particularly useful method of tin-
flowing inductive heating is in actual practice rarely employed and the method of heating the strip by the direct passage of a current therethrough is preferred. However, this latter method also suffers from various drawbacks when applied to the purpose in view.

There is therefore a pronounced need for the provi-
sion of apparatus based on the use of induction coils which embrace the strip and which, on the one hand, are robust and reliable in operation and, on the other hand, capable of providing high and maximum power. By means of a motor-generator-set frequencies within a range of from 500 to 10,000 cycles per second can be obtained and when herein and in the claims hereof we use the term "medium frequencies" we mean fre-
quencies so produced in this range, although for the purposes of the invention the best range is from 1,000 to 10,000 cycles per second. It has been found to be possible when using such a plant operating at such frequencies to obtain an unexpected effect if the power density is kept very low. As known, it is the general custom in induction heating to operate at high power densities—in the case of 10,000 cycles this may be 1 kw./sq. cm. and even more—because it was generally supposed that the advantages of inductive heating could only then be fully exploited. The inventors now pro-
pose to break away from this general preconceived notion by employing a power density of not more than 20 watts/sq. cm. in operating inductors which induct-
ively affect the strip. When the power density is thus substantially reduced the permeability of the ferritic ma-
terial of the strip rises to such an extent that the depth of electrical penetration becomes very small and the temperature of the strip is thus sufficiently raised to permit the coating of tin to flow as desired.

It is preferred that the power density should be less than 10 watts/sq. cm. and that the frequency should be 10,000 cycles per second. The efficiencies that can then be achieved are outstanding. This is due to the fact that the reduction in power density brings about a concomitant increase in permeability improving the sus-
ceptibility of the sheet above that of the surrounding air to such an extent that despite an indifferent coupling factor the greater part of the magnetic field emanating from the coil will be drawn into the strip. The resultant electric coupling factor becomes more favourable, the efficiency improves, and a favourable power factor ensu-
es. Even in the case of strip only 0.15 mm. thick a good heating efficiency can be achieved even with a frequency of only 5000 cycles per second.

In the further development of the method proposed by the invention it is proposed to build up the magnetic field acting upon the strip from components which cross the strip at an angle to the direction of travel, without of course at the same time increasing the power density. The consequence of such an arrangement is that the flux will traverse the strip not only in the longitudinal but also in the transverse direction. The vectorial addition of the two components produces a resulting vector which depending on its magnitude will pass through the plane of the strip at a greater or smaller angle of inclination. In any case this vector will be longer than the thickness of the strip so that the resultant conditions will be favourable in relation to depth of penetration.

To perform this method the invention proposes to
employ an induction coil consisting of lengths of conductor which cross the strip at right angles but which in the region of the strip edges rise from one side of the strip to the other at an angle exceeding 25°. The accompanying drawing illustrates such an inductor in more or less diagrammatic form, and the invention will now be more particularly described with reference to the illustrated form of construction.

Fig. 1 shows the inductor when viewed from above, whereas Fig. 2 is an axial longitudinal section.

The inductor which embraces the strip 1 comprises individual winding sections which alternately run across the strip 1 above and below. In Fig. 1 the sections 2 are located under the strip, whereas those marked 3 cross above the strip. Both these sections 2 and 3 cross the strip at right angles to the edge of the strip 1, and they are connected by rising and falling curved portions 4 around the edges pitched at an angle normal to the strip that exceeds 25°, as shown especially in Fig. 2. The coil therefore actually has a meandering shape with transverse sections raised and lowered above and below the level of the strip so that the strip 1 can pass in the medial plane between them. The result of this conformation is that the resultant magnetic field is not uniform and equally maintained by all the turns of the coil, but that each turn produces its own magnetic field which surrounds it, only a few lines passing through and surrounding the whole of the coil. The resultant vectors must therefore pass through the strip at a greater or lesser angle of inclination.

The method according to the invention, especially if it is performed with the help of an inductor of the kind herein proposed and described permits ferritic sheet and strip to be satisfactorily heated in continuous progression with low installed power by the application of frequencies between 5000 and 10,000 cycles per second, to the temperatures required for flowing a previously applied coating of tin. Temperatures of 200 to 300° can be readily produced even if the velocity of travel is as high as 100 metres per minute and even more.

What we claim is:

1. Method of progressively inductively heating ferritic strip, of a thickness not less than 0.10 mm. or more than 0.35 mm. to a temperature not less than 200° C. or more than 300° C. by means of at least one induction coil embracing the strip and operating with current at medium frequency, and at a power density of not exceeding 20 watts/sq. cm.

2. Method according to claim 1 in which the magnitude of the frequency is selected from the group of magnitudes consisting of 10,000 and 5000 cycles per second and frequencies intermediate these magnitudes.

3. An induction coil for carrying out the method according to claim 1, comprising conductor sections arranged to cross the sheet or strip at right angles in relation to its edges and having connecting portions to extend around the edges of the sheet or strip from one side to the other of the latter at an angle of pitch not less than 25°.

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