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3,448,233

INDUCTION HEATING ASSEMBLY

Filed Sept. 26, 1967

Sheet 1 of 2

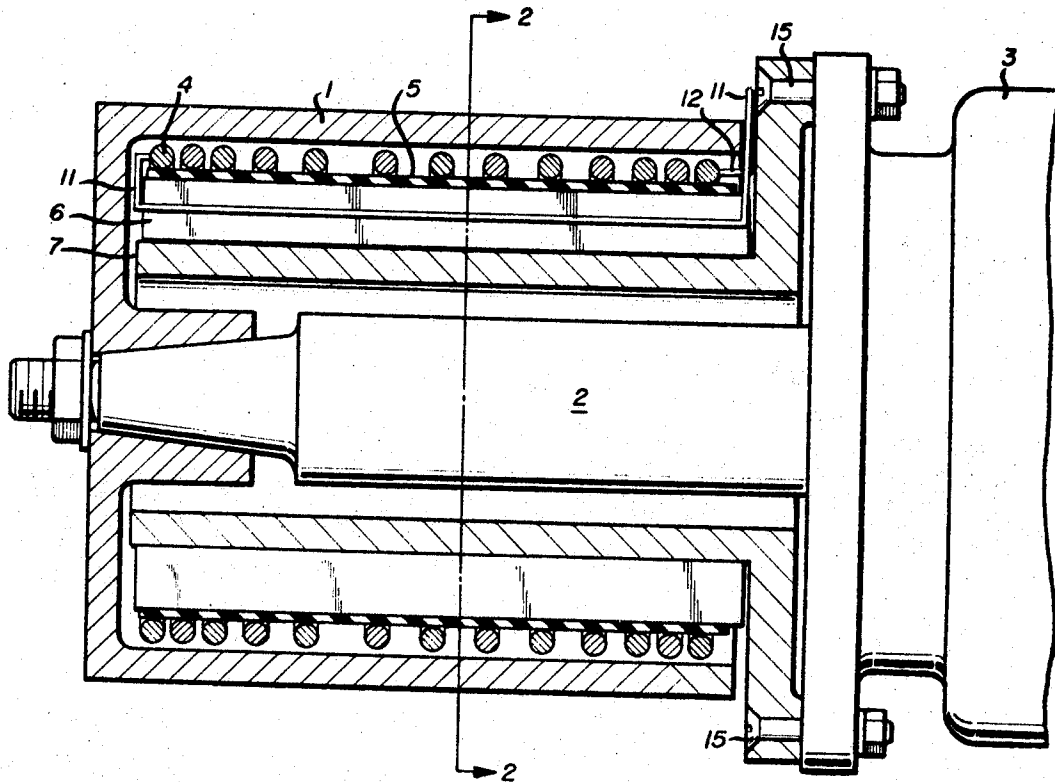


FIG. 1

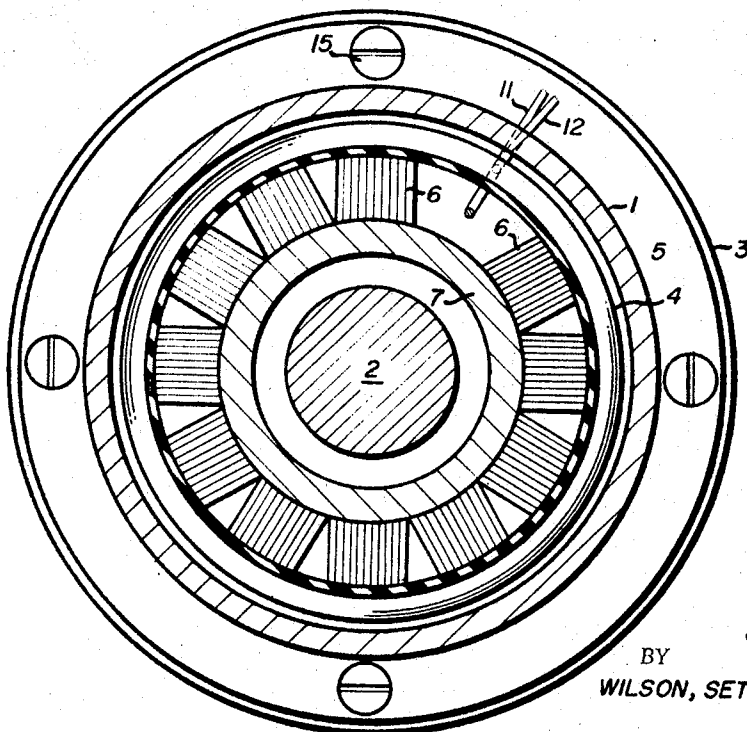


FIG. 2

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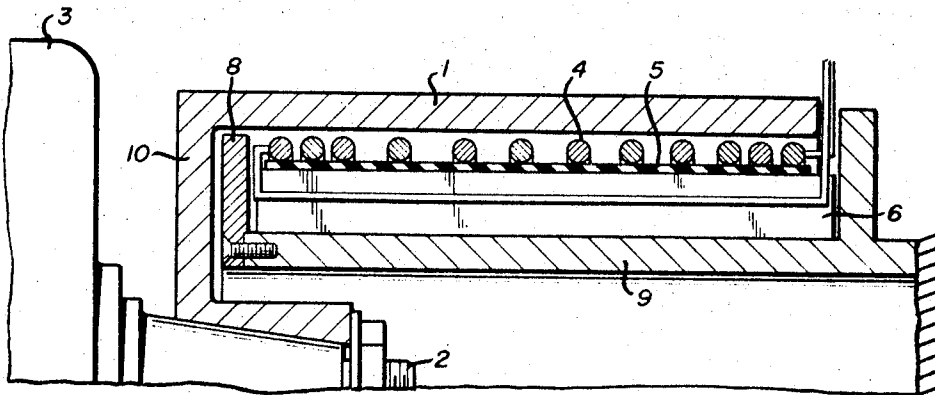


FIG. 3

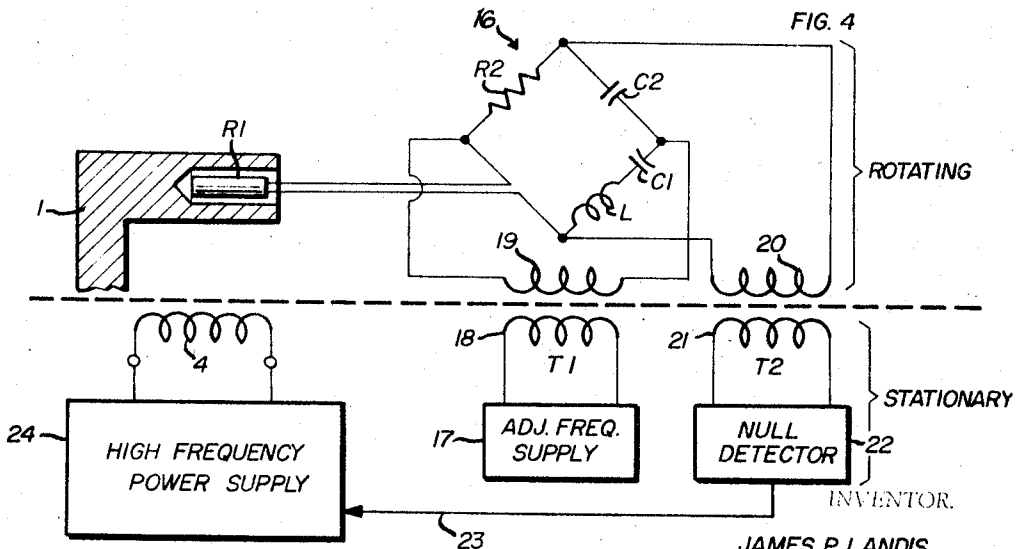
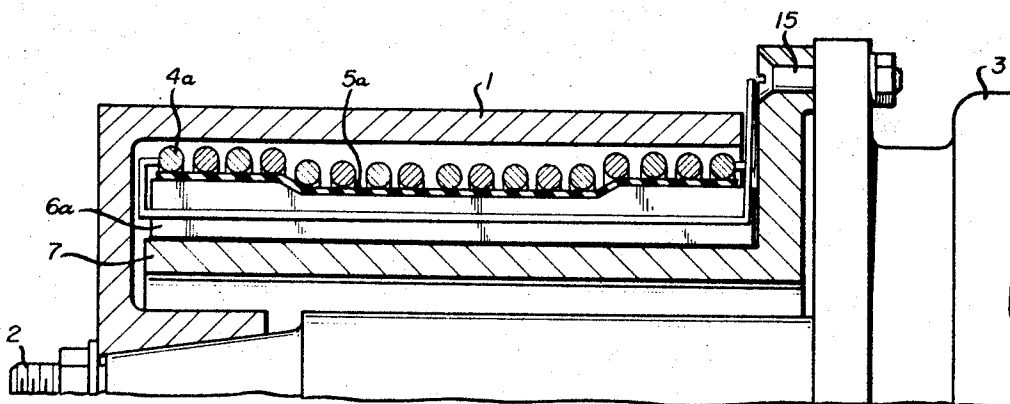


FIG. 5

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3,448,233

INDUCTION HEATING ASSEMBLY

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U.S. Cl. 219—10.61

17 Claims

ABSTRACT OF THE DISCLOSURE

A hollow, rotating roller is heated by induction by means of a stationary coil mounted within the roller and wound helically along but spaced from the inner surface of the roller. The pitch and/or the spacing between the coil and roller is varied along the length of the coil to compensate for unequal heat losses at different portions of the roller. A magnetic core is located inside the coil to provide a low reluctance return path for the magnetic flux within the coil and thus divert flux from other nearby structures. A highly conductive shield member is located adjacent and generally within the core and acts as a barrier to the penetration of alternating magnetic flux.

Background of the invention

This invention relates to a system or assembly for heating process rollers. More particularly, the invention relates to a system wherein heat is applied to a roller by induction in a manner permitting close definition of the roller areas to be heated and minimizing the undesirable side effects of stray fields and currents.

Heated rollers, rolls or wheels are widely used in the continuous processing of such materials as fibers, films, coated fabrics, paper, etc. For example, in the processing of fibers, the fibers are passed around and in contact with heated rollers in order to heat the fibers to modify their characteristics, and this heating operation is much like an annealing operation in the treatment of metals. Some of the requirements connected with the operation of such rollers are high speed of operation, high thermal power density in the roller, an unobstructed access to the outer surface of the roller, and the need for close control of the temperature of the roller.

In addition, the mechanical power required to drive the roller may be very low relative to the high thermal power needed to heat the roller.

The use of an internally mounted induction coil as a means for generally meeting the above roller heating requirements has long been known (for example, see U.S. Patent 1,701,156 to Heritage). Induction heated rollers have not, however, been broadly used in the process industries because of problems such as non-uniform heating of the roller, excessive stray magnetic fields which may produce heat where it is not wanted, and development of excessive retarding torque on the roller which increases the mechanical power requirements needed to drive the roller.

Objects of the invention

It is an object of this invention to provide an improved induction heating assembly in which an inductively heated process roller has high power density per unit of surface area.

Another object of the invention is to provide an inductively heated roller wherein the torque reaction on the rotational driving means for the roller is minimized.

Another object is to provide an inductively heated roller wherein the pattern of power density per unit of

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axial length of the roller can be predetermined to suit process requirements.

Another object is to provide an inductively heated roller wherein the paths of the magnetic fields are constrained to avoid undesirable heating in roller support members and other nearby non-heated parts.

A further object is to provide an inductively heated roller wherein the material of the roller can be selected to suit process requirements without limitation to a given electrical resistivity or magnetic permeability.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

On the drawings

FIGURE 1 is a central section of an induction heating assembly embodying the invention and utilizing a motor as a means of support;

FIGURE 2 is a cross-sectional view of the assembly taken along line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary sectional view similar to FIGURE 1 but showing an alternative embodiment of the invention;

FIGURE 4 is a fragmentary sectional view similar to FIGURE 1, but showing a second alternative embodiment of the invention; and

FIGURE 5 is a block diagram of an energizing and control system for operating an induction heating assembly of the type shown in FIGURES 1 through 4.

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

As shown on the drawings

Referring to FIGURE 1 and FIGURE 2, a hollow, cylindrical, electrically conductive roller 1, supported by the shaft 2 of motor 3, is the element to be heated, generally for the purpose of transferring heat to material (not shown) passing in contact with its outer cylindrical surface. Helically wound coil 4 is concentrically and closely disposed relative to the cylindrical inner surface of roller 1 and is energized by a source of alternating or pulsating direct voltage. Flow of current in coil 4 induces voltages in roller 1 resulting in current flow in roller 1. These currents will flow predominantly close to the inner surface of roller 1 and following a path directly in axial alignment with the individual turns of coil 4. Thus, the intensity of heat input to any axial portion of the roller can readily be predetermined by adjusting the pitch of the axial portion of the coil associated with said axial portion of the roller. By way of example, coil 4 is shown to be more closely pitched at the ends than at the center. Greater heat input per unit of axial length would therefore be provided at the ends, as might typically be required to offset greater heat losses at roller ends owing to windage, etc. In this example, the pitch of the coil has been varied to make the temperature of the roller substantially uniform along the length of the coil.

Insulating sleeve 5 serves to isolate coil 4 electrically from magnetic laminated core 6. Core 6 consists, ideally, of iron laminations individually disposed radially but here shown radially disposed in groups as representing a more easily achieved construction. Core 6 provides a return path of low reluctance for the magnetic flux within the

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coil. This low reluctance path serves to divert the flux from alternate undesirable paths, such as through shaft 2 or other nearby structural members. Additionally, the low reluctance path reduces the magnetomotive force required to establish the magnetic field, thereby decreasing required coil current and increasing system power factor.

Annular shielding member 7 is constructed of highly conductive material such as copper or aluminum. This shielding member supplements the flux diverting action of the core by presenting a barrier to the penetration of alternating magnetic flux. Thus, shaft 2 which extends through the assembly will not be linked by flux and so will not be heated. Since the barrier action of the shielding member is accomplished by the generation of surface eddy currents in the shielding member, some loss is experienced even though copper or aluminum of high conductivity is used. Hence, the shielding demand should normally be minimized by providing an appropriate core, as shown, to divert as much flux as possible. Shielding member 7 may be mounted on motor 3 as by screws 15 and serves as a support for the core and coil elements. Shield 7, core 6, sleeve 5 and coil 4 are all stationary, whereas shaft 2 rotates roller 1. Alternative means of support, such as a sleeve of steel or other structural material concentric with, and surrounded by shielding member 7, could be used.

Lead 11 connected to coil 4 may be brought out to the exterior of the assembly by omitting one of the lamination bundles for core 6 (FIG. 2) and running lead wire 11 through this space as shown. Lead wires 11 and 12 may then extend around the free end of roller 1 as shown.

FIGURE 3 illustrates an alternate means of support for the core and coil elements utilizing shielding member 9 connected to a support surface separate from the motor. Also illustrated by FIGURE 3 is an additional shielding ring 8 which could be used to prevent flux penetration into the web portion 10 of the roller 1 if heating of said portion is not desired. Since the currents induced in the shielding members 9 and 8 flow circumferentially, electrical continuity should preferably be provided along such paths. Axial continuity is not required, thereby rendering unnecessary a highly conductive joint between shielding members such as 8 and 9.

FIGURE 4 illustrates an alternative construction incorporating a non-uniform radial spacing between the coil 4a and the inner surface of the roller 1. The diameter of coil 4a varies along its length to provide this non-uniform spacing. Increased spacing decreases the effective electromagnetic coupling between coil and heated member thus reducing the heating power per unit of coil current. The arrangement of FIGURE 4 produces less heat per axial unit of length in the central portion of the roller than in the end portions, and with this arrangement, the temperature of the roller is substantially uniform along its length. Thus, by proper selection of radial spacing, as shown by FIGURE 4, or by selection of coil pitch, as shown by FIGURES 1 and 3, or by a combination of both, the relative heating intensity over any increment of axial length can be predetermined. The construction of the assembly of FIGURE 4 is similar to that of FIGURE 1, the only difference being that coil 4a, sleeve 5a and core 6a have reduced diameter central portions to accommodate the non-uniform spacing between coil 4a and roller 1.

In some applications for heated rollers, the mechanical power required for rotation is very low compared to the power required for heating. It is therefore essential that the heating be accomplished, to the greatest extent practicable, by transformer action rather than by conversion of mechanical power to heat. To this end, the assembly should so direct the fluxes and currents to produce little or no torque reaction. No torque reaction can be produced if all current paths in the roller are purely circumferential and all flux paths are purely axial and radial. To approach this ideal condition, the coil pitch should be made as close as practicable, the magnetic

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structure should be made as nearly symmetrical circumferentially as practicable, and the concentricity of the inner roller surface, coil, and core should be held as close as practicable. Where absolute minimum torque reaction is required, a core consisting of individual radially disposed laminations would be an improvement over the bundled laminations of FIGURE 2, as would be also a core of substantially homogeneous magnetizable material, such as ferrite, which would be made with complete circumferential symmetry. Furthermore, in such critical applications an alternate routing for lead wire 11 would be preferred to preserve core symmetry.

FIGURE 5 is a schematic diagram showing the basic elements of a system for controlling the temperature of the roller 1. The latter temperature is sensed by a temperature sensitive resistor R1 which constitutes one arm of an impedance bridge 16. The bridge consists of resistors R1 and R2, inductor L and capacitors C1 and C2, and the bridge rotates with the roller 1. The bridge is fed from an adjustable frequency source 17 via a transformer T1 having a stationary primary winding 18 and a rotating secondary winding 19. A similar rotating transformer T2, consisting of a rotating primary winding 20 and a stationary secondary winding 21, is used to supply the bridge output to a null detector 22 as shown. The null detector supplies an output via line 23 to a high frequency power supply 24 which in turn supplies energizing power to coil 4 which heats roller 1.

In operation, the desired temperature for roller 1 is preset by setting the frequency of the adjustable frequency supply 17. The bridge 16 will balance only at one value of resistance R1 such that:

$$R1 = (R2)(2\pi f C_2) \left(\frac{1}{2\pi f C_1} - 2\pi f L \right)$$

The condition of bridge 16 is continuously monitored by the null detector 22 which, in turn, produces an appropriate command to the high frequency power supply 24. This command will raise or lower the power level supplied to coil 4 from high frequency supply 24 so as to maintain a level of temperature at R1 to keep the bridge in balance.

Having thus described my invention, I claim:

1. An induction heating assembly comprising a hollow, electrically conductive roll having an inner surface to be heated by induction, means mounting said roll for rotation about an axis, stationary support means within said roll, a continuous, stationary, conductive coil on said support means concentric with said axis of rotation and wound substantially helically along but spaced from the inner surface of said roll, and a power supply connected to said coil for energizing the same with alternating or pulsating current, said coil having a concentration of turns per unit of axial length and a spacing from said roll inner surface at least one of which varies along the axial length of said coil so that, when said coil is energized electrically by current from said power supply to heat said roll by induction, said coil induces in said roll a predetermined non-uniform pattern of power density per unit of axial length of said roll.

2. An induction heating assembly as claimed in claim 1 in which the concentration of turns per unit of axial length of said coil varies along the axial length of said coil.

3. An induction heating assembly as claimed in claim 2 in which the concentration of turns per unit of axial length of said coil at first and second portions thereof aligned with end portions of said roll is greater than at an intermediate portion of said coil between said first and second portions thereof.

4. An induction heating assembly as claimed in claim 3 in which the said variation in concentration of turns of said coil provides a substantially uniform temperature in said roll when said roll is heated by electrically energizing said coil.

5. An induction heating assembly as claimed in claim 1 in which the spacing of said coil from said roll inner surface varies along the axial length of said coil.

6. An induction heating assembly as claimed in claim 5 in which the diameter of said coil at first and second portions thereof aligned with end portions of said roll is greater than at an intermediate portion of said coil between said first and second portions thereof.

7. An induction heating assembly as claimed in claim 6 in which the variation in diameter of said coil provides a substantially uniform temperature in said roll when said roll is heated by electrically energizing said coil.

8. An induction heating assembly as claimed in claim 1 in which said assembly includes an annular, electrically conductive shield member located concentrically within and electrically insulated from said coil for preventing flux generated by said coil from penetrating to the inside of said shield member.

9. An induction heating assembly as claimed in claim 8 in which said shield member is a part of said support means.

10. An induction heating assembly as claimed in claim 8 in which said mounting means for said roll includes a shaft located inside said shield member and protected by said shield member from flux generated by said coil in the operation thereof.

11. An induction heating assembly comprising a hollow, electrically conductive roll having an inner surface to be heated by induction, means mounting said roll for rotation about an axis, a continuous, stationary, conductive coil within said roll concentric with said axis, said coil being substantially helical and extending along but spaced from said inner surface of said roll for heating said roll by induction upon energization of said coil, said coil having a concentration of turns per unit of axial length thereof and a spacing from said roll inner surface at least one of which varies along the axial length of said coil to produce a non-uniform pattern of power density per unit of axial length of said roll, and an annular electrically conductive shield member located concentrically within and electrically insulated from said coil for preventing flux generated by said coil in the electrical operation thereof from penetrating to the inside of said shield member.

12. An induction heating assembly as claimed in claim 11 in which said mounting means for said roll includes a shaft located inside said shield member and protected by said shield member from flux generated by said coil in the electrical operation thereof.

13. An induction heating assembly as claimed in claim 12 and further including a low reluctance magnetic core disposed between said shield member and said coil providing a low reluctance return path for magnetic flux within said coil and serving to divert flux from alternate undesirable paths including said shaft.

14. An induction heating assembly as claimed in claim 13 in which said core is substantially symmetrical about said axis of rotation of said roll.

15. An induction heating assembly as claimed in claim 14 in which said core comprises a plurality of laminated structures disposed circularly about said axis, each said laminated structure being composed of iron laminations extending generally radially with respect to said axis.

16. An induction heating assembly comprising a hollow, electrically conductive roll having an inner surface to be heated by induction, means mounting said roll for rotation about an axis, stationary support means within said roll, and a stationary conductive coil on said support means concentric with said axis of rotation and wound substantially helically along but spaced from the inner surface of said roll, said coil having a diameter at first and second portions thereof aligned with end portions of said roll greater than at an intermediate portion of said coil so that the spacing between said coil and said roll inner surface varies along the axial length of said coil to provide a substantially uniform temperature in said roll when said roll is heated inductively by energization of said coil.

17. An induction heating assembly comprising a hollow, electrically conductive roll having an inner surface to be heated by induction, means mounting said roll for rotation about an axis, a stationary conductive coil within said roll concentric with said axis, said coil being substantially helical and extending along but spaced from said inner surface of said roll for heating said roll by induction upon energization of said coil, an annular electrically conductive shield located concentrically within and electrically insulated from said coil, said mounting means for said roll including a shaft inside said shield member and protected by said shield member from flux generated by said coil in the electrical operation thereof, and a low reluctance magnetic core disposed between said shield member and said coil and serving to divert flux from alternate undesirable paths including said shaft, said core comprising a plurality of laminated structures disposed circularly and substantially symmetrically about said axis, each said laminated structure being composed of iron laminations extending generally radially with respect to said axis.

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