Nov. 19, 1968 HARUMI MIYAGI 3,412,228

HEATING ROTARY DRUM APPARATUS

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FIG.1.

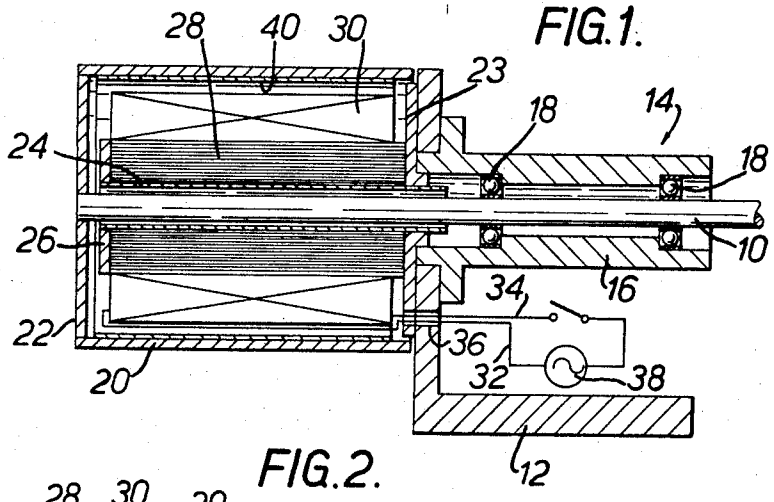


FIG.2.

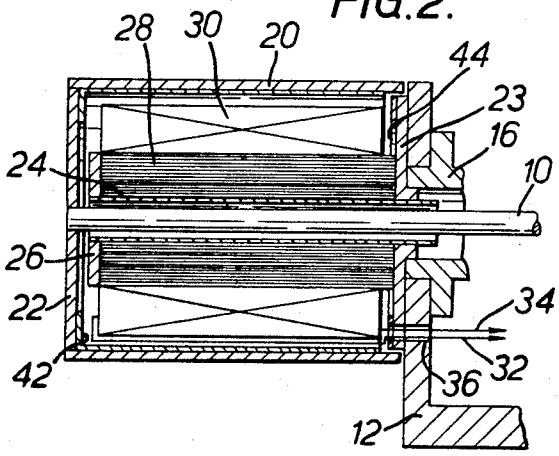
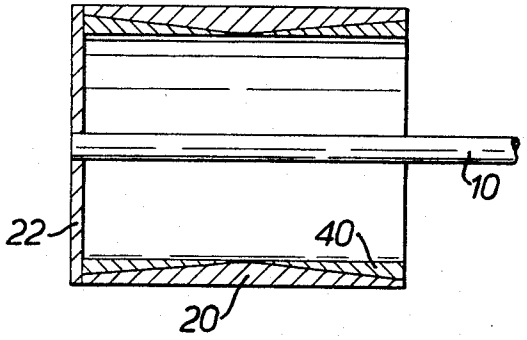


FIG.3.



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FIG.4.

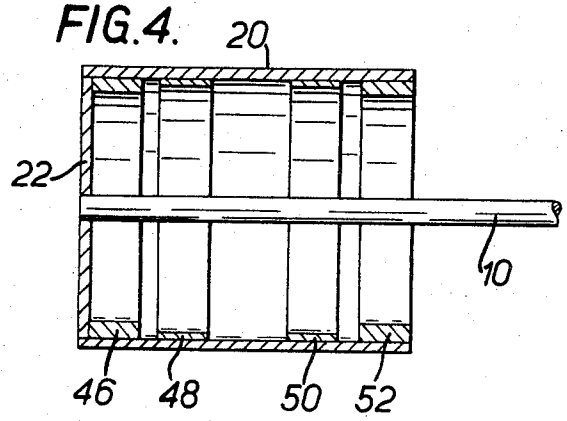


FIG.5.

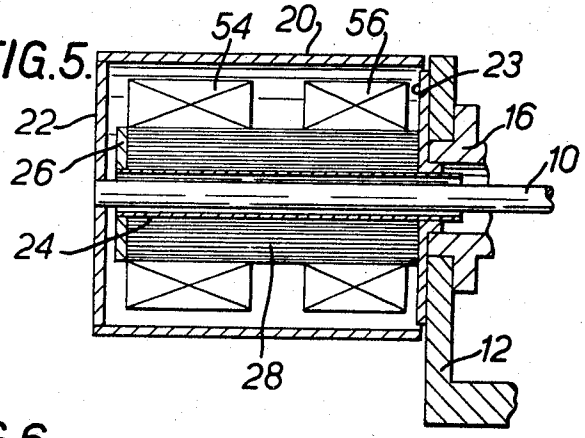
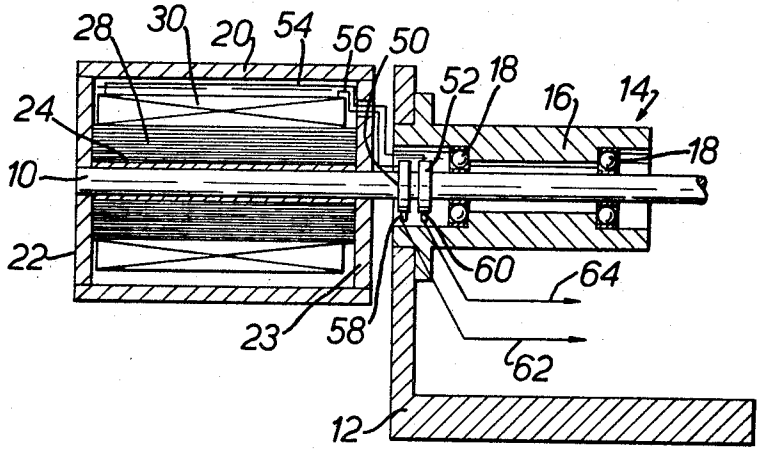


FIG.6.



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HEATING ROTARY DRUM APPARATUS

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9 Claims. (Cl. 219—10.61)

ABSTRACT OF THE DISCLOSURE

This disclosure relates to an apparatus provided with a rotary drum for use in heating a fiber, filament, tape or the like as it passed around the drum surface. The rotary drum is heated by electric currents electromagnetically induced therein with various embodiments being disclosed for obtaining different amounts of heating along the length of the drum.

In the process of manufacturing or treating synthetic fibers, for example, it is often required to apply heat to the fibers as they are being run. In the prior art a roller or drum enclosing an electric resistance wire such as Nichrome wire has been in wide use. With such a drum, since the heat produced by the resistance wire is transferred to the drum surface by radiation, a great loss in the amount of heat transferred from the wire to the drum is caused. Moreover, as the drum is rotated, a centrifugal force is always being applied to the wire often to break it, with a resulting reduction in the processing efficiency and a considerable loss in time due to stoppage of the running of the apparatus for repair or replacement of the broken wire.

Accordingly, the primary object of the invention is to provide a heating apparatus having a rotary drum which is heated by electric currents electromagnetically induced.

Another object of the invention is to provide an apparatus as aforesaid having a rotary drum which is heated by a current electromagnetically induced in a closed circuit composed of the drum wall and eddy currents also electromagnetically induced in the drum wall.

Another object of the invention is to provide an apparatus as aforesaid which includes a rotary drum heated by electric currents electromagnetically induced in such a manner that the temperature of the circumferential wall of the drum is kept substantially uniform all over.

Other objects, features and advantages of the invention will become more apparent during the course of the specification.

Briefly stated, the apparatus in accordance with one embodiment of the invention comprises a shaft having a portion thereof rotatably received in bearing means and rotated by a suitable drive means, and a drum mounted on the shaft for rotation therewith. Within the drum there is provided an iron core encircling the shaft, with a coil wound on the core and energized by an alternating current source. Upon energization of the coil, an alternating flux is emitted from one end of the core and passes through the drum wall axially thereof to return to the opposite end of the core. Since a closed circuit is formed in the drum wall circumferentially thereof and in a plane normal to the axis of the rotating shaft, the circuit links with the alternating flux, with resulting electromagnetic induction of a current through the closed circuit. On the other hand, since the magnetic flux passes through the drum wall axially thereof, eddy currents are induced therein. Due to the circumferential current and the eddy currents Joule's heat is produced to heat the drum wall, which may be utilized for heating purposes.

The invention will be better understood from the following detailed description of preferred embodiments thereof with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic elevational view, in longitudinal section, of one embodiment of the invention; and

FIGS. 2 through 6 are views similar to FIG. 1 but showing other different embodiments of the invention, with FIGS. 3 and 4 showing the drum and its mounting shaft only.

Now referring in detail to the drawings, there is shown in FIG. 1 a shaft **10** adapted to be rotated in one direction by a suitable drive means such as an electric motor, not shown. A fixed base **12** supports a bearing means **14** which comprises a hollow cylindrical member **16** of a suitable length fixed to the base **12**. In the cylindrical member **16** there are a plurality of ball bearings **18** axially spaced apart, in which the shaft **10** is received. A hollow roller or drum **20** made of a suitable magnetic material such as, for example, cast iron has its one end being open and the opposite end closed by an end plate or disc **22** of a magnetic material. The shaft **1** has its outer end rigidly secured to the center of the disc **22** for simultaneous rotation of the shaft and the drum.

As will be described hereinafter, since a part of the base **12** forms a part of the magnetic path through which alternating flux is to pass, the base **12** must be made of a magnetic material, with its portion being arranged adjacent the open end of the drum **20** as if to close that open end. Otherwise, a disc **23** of a magnetic material is disposed adjacent the open end of the drum **20**, as shown in FIG. 1.

Inside the drum **20** and concentrically therewith there is provided a support tube **24** through which the rotatable shaft **10** loosely passes. The tube **24** has its one end rigidly fixed to the base **12** or the disc **23** and the opposite outer end provided with an end disc **26**. An iron core **28** encircles the support tube **24**, extending between the two opposite discs **23** and **26**. Preferably, the core **28** is made of a silicon steel plate rolled in many layers around the tube **24** so that the core is circular in transverse section. Since the core **28** links with the magnetic flux produced as will be described later, an electric current would flow circumferentially of the core so that the core would also be heated by Joule heat. To reduce Joule heat, a radial groove or slit, not shown, may advantageously be formed in the core along the whole length thereof and filled up with an electrical insulating material so as to break the closed circuit which would otherwise be completed in the core to link with the alternating flux.

A coil **30** is wound on the core **28** and is connected to an alternating current source **38** by a pair of leads **32** and **34** passing through a hole **36** formed in the disc **23** and the wall of the base **12**.

Upon energizaton of the coil **30** by an alternating current from the source **38**, there is developed in the core **28** an alternating magnetic flux, which is emitted from one end, say, the left-hand end of the core **28** and passes radially outwardly through the end plate **22** of the drum, then axially through the circumferential wall thereof and then radially inwardly through the opposite plate **23** and finally reaches the opposite end of the core **28** to enter thereinto. Through this magnetic path the flux alternates.

Since the flux passes through the circumferential wall of the drum axially thereof, the flux and the drum wall **20** link with each other, so that a current is induced in the drum wall in a plane normal to the axis of the drum. In other words, a current flows in the drum wall circumferentially thereof. This is apparent from the well known principle of operation of a transformer. Suppose that the

coil **30** be the primary winding of a transformer. The circumferential wall of the drum **20** will be the secondary winding consisting of a single closed turn placed concentrically with the primary winding. Therefore, eletcromagnetic induction causes electric current to flow through the drum wall circumferentially thereof. This current may be referred to as a short-circuit current since it flows in the closed circuit composed of the circumferential wall of the drum.

On the other hand, as the alternating flux passes through the drum wall axially thereof, the electromagnetic induction also causes eddy currents to be produced in the drum wall. Due to the short-circuit current and eddy currents Joule heat is produced to heat the drum **20**. Upon rotation of the shaft **10** the drum **20** is rotated while being heated. As a fiber or filament, not shown is passed around the heated drum wall **20** in a few turns, it becomes heated as required in the process.

In the embodiment of FIG. 1, the circumferential wall of the drum **20** has its inner surface covered with a layer or sleeve **40** of a highly electrically conductive material. Metalizing the inner surface of the drum wall with copper will be a simple way of forming such an inner layer. The layer **40** then provides another closed circuit in parallel with the closed circuit provided by the drum wall. The combined impedance of the parallel closed circuits is lower than the impedance of the single closed circuit provided by the drum wall, with a resulting increase in the amount of short-circuit current and consequently Joule heat produced. With the same apparent power of the alternating current source **38**, since a greater amount of short-circuit current flows with the presence of the inner layer **40** than without it, as mentioned just above, the power produced in the drum wall is increased with a resulting increase in the power-factor of load. This is another advantage resulting from the provision of the additional layer **40**.

As previously described, the drum of the invention is heated by the short-circuit current and eddy currents produced by electromagnetic induction, and the short-circuit current is induced by the circumferential wall of the drum linking with the alternating flux. The flux, however, passes through the discs **22** and **23**, so that a smaller number of magnetic flux lines link with the opposite end portions of the circumferential wall of the drum **20** than the other portions thereof. This means that a smaller amount of short-circuit current is induced in the areas of the drum wall toward the opposite ends thereof. Consequently, the temperature of the drum wall tends to become higher in the central area along the axis of the drum wall and lower toward the opposite end portions thereof. This certainly is undesirable in view of the heating purpose of the drum. Toward solving the problem and providing a substantially uniform temperature distribution in the drum wall, the arrangements of FIGS. 2 through 5 are directed.

In FIG. 2, both the discs **22** and **23** have their respective inner surfaces covered by electrically conductive annular layers or rings **42** and **44** formed in the same manner as that of forming the layer **40**. Then the alternating flux passing through the discs **22** and **23** will link with the conductive layers **42** and **44** and cause another short-circuit current to be induced to flow therethrough. Due to this current the layers **42** and **44** will be heated for the heat to be transferred to the opposite end portions of the circumferential wall of the drum so as to raise the temperature of these portions higher than it would be without the layers **42** and **44**, thereby effecting a uniform tempearture distribution over the whole area of the drum wall.

In order to induce a greater amount of short-circuit current near the opposite end portions of the drum wall than in the central portion thereof, the layer **40** may be made thicker toward the opposite ends thereof, as shown in FIG. 3. For the same purpose, the layer may be replaced by a plurality of electrically conductive rings **46**, **48**, **50** and **52** (FIG. 4) placed on the inner surface of the drum wall and equidistantly spaced apart along the axis of thereof, with the rings **46**, **52** positioned at the opposite ends being thicker than the other rings placed toward the center. It will be easily understood that a greater amount of short-circuit current is induced in the areas toward the opposite ends of the drum wall than the central area thereof because of a smaller resistance provided by the greater thickness of the opposite end portions of the layer **40** in FIG. 3 or of the rings **46** and **52**. Thus, the temperature of the opposite end portions of the drum wall will be raised to that of the central area thereof, thereby accomplishing a uniform temperature distribution all over the drum wall.

In FIG. 5, a uniform temperature of the drum wall is effected by distributing leakage flux as evenly as possible. In the arrangement of FIG. 1, all the flux produced do not pass through the whole length of the iron core **28**, but some flux pass through only a part of the iron core and leak out therefrom to pass through a part of the drum wall. It will be easily seen that there exists more leakage flux in the central portion of the length of the coil **30** than any other portions thereof and, consequently, the temperature of the drum wall tends to become higher toward the central portion of the length thereof. To avoid this, in FIG. 5 the single coil **30** of FIG. 1 is divided into a plurality, say, a pair of coils **54** and **56**, which are positioned toward the opposite end portions of the iron core **28**, with a resulting substantially uniform distribution of the leakage flux. Thus the temperature of the drum wall can be kept at a substantially uniform level all over.

In FIGS. 1 through 5, the drum **20** is rotated while the iron core **28** with the coil or coils thereon is held stationary. If desired, the latter may also be rotated together with the former. FIG. 6 shows by way of example such an arrangement, wherein the support tube **24**, iron core **28** and coil **30** are all rigidly fixed to the rotatable shaft **10** and also the disc **23** is rigidly fixed to the shaft **10** and the drum wall **20**. A pair of slip rings **50** and **52** are connected to the coil **30** by leads **56** and **54**, respectively, and rigidly mounted on the shaft **10** for rotation therewith. A pair of brushes **58** and **60** connected to an alternating current source by leads **62** and **64** are arranged in sliding contact with the rings **50** and **52**, respectively, so that while the shaft **10** with the parts mounted thereon is being rotated, the coil **30** is energized without fail.

Having illustrated and described preferred embodiments of the invention, it should be recognized that there are many other modifications and changes within the scope of the invention as defined in the appended claims.

What I claim is:

1. A heating rotary drum apparatus for use in heating purposes comprising: a shaft adapted to be rotated by a drive means; a drum arranged concentrically with said shaft and having a circumferential wall and an end disc, both formed of a magnetic material, said end disc closing one of the opposite end openings of said circumferential wall and being rigidly mounted at its center on said shaft for rotation of said drum with said shaft; a plate formed of a magnetic material and disposed adjacent the opposite end opening of said drum; an iron core enclosed and arranged within said drum concentrically with the axis of said shaft; a coil wound on said iron core and connected to an alternating current source to be energized thereby; and conductive means disposed on the interior of said drum including a conductive layer disposed on the interior of said circumferential wall, said conductive means being so disposed on the interior of said drum that more conductive material is disposed near the portion of said wall adjacent said disc than at the center of said wall, whereby greater currents will be induced at the end of said wall and a uniform temperature thereby obtained.

2. The apparatus as defined in claim **1**, wherein said

disc and plate are provided on their respective inner surfaces with an electrically conductive layer.

3. The apparatus as defined in claim 1, wherein said electrically conductive layer is formed thicker toward the opposite ends thereof along the axis of said drum.

4. The apparatus as defined in claim 1, wherein said circumferential wall is provided on its inner surface with a plurality of electrically conductive layers, those of which positioned at the opposite end portions of said wall are thicker than the others.

5. A heating rotary drum apparatus for use in heating purposes comprising means for developing an alternating magnetic flux, a rotatable ferromagnetic drum having a circumferential wall with an external surface of predetermined axial length and adapted to be contacted by an article to be heated, said drum being magnetically coupled to said flux developing means and positioned relative thereto to provide a predetermined low-reluctance flux path, and means, including at least one closed electrical circuit carried by said drum, having an impedance less than that of said drum and positioned generally perpendicular to said flux path and linked by said alternating magnetic flux for generating heat in response to a flow of current induced in said circuit by interception of said flux and for conducting such heat to said external surface of said drum wall, the resistance of said heat generating and conducting means varying along the axial length of said drum in a predetermined uneven manner such that the current flow induced therein and the resulting heat generation are greater at locations of lower resistance whereby more heat is conducted to predetermined corresponding portions along the axial length of the external surface of said drum wall.

6. A heating rotary drum apparatus as claimed in claim 5 wherein said means for developing an alternating magnetic flux is stationary.

7. A heating rotary drum apparatus as claimed in claim 6 wherein said means for developing an alternating magnetic flux is positioned within said ferromagnetic drum.

8. A heating rotary drum apparatus as claimed in claim 5 wherein said means for developing an alternating flux comprises a transformer primary and said heat generating and conducting means comprises a plurality of independent transformer secondaries positioned at selected points within said ferromagnetic drum to provide a predetermined temperature profile on said external surface of said drum wall.

9. A heating rotary drum apparatus as claimed in claim 5 wherein the resistance of said heat generating and conducting means varies in a manner which provides a uniform temperature distribution along the external surface of said drum.

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