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WIRE WINDING APPARATUS
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FIG. 1

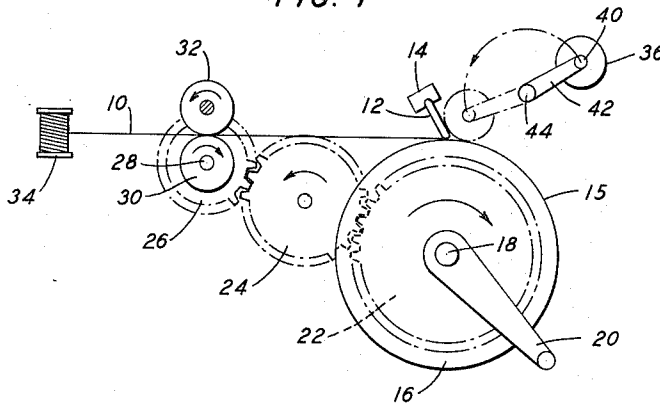


FIG. 2

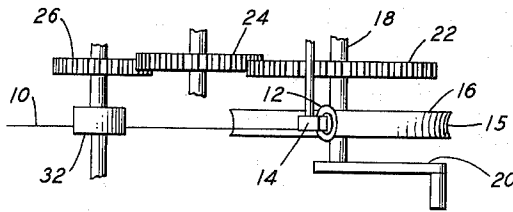
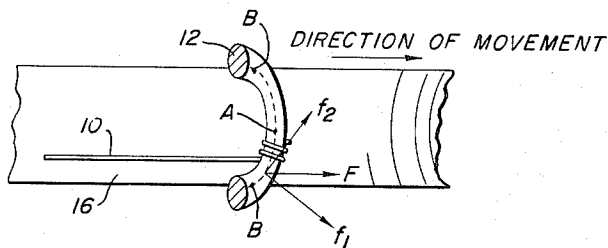


FIG. 3



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1

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WIRE WINDING APPARATUS

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2 Claims. (Cl. 72-145)

This pertains to wire winding apparatus and particularly to apparatus for winding a wire around a support.

The use of magnetic cores in electronic circuits is presently limited due to the cost of winding coils around the cores. This problem lies in the unique magnetic and electronic requirements placed on the cores. The magnetic circuit requires a closed path such as a toroid. The electronic circuit requires a number of coils wound on each core and each coil may comprise as many as thirty turns. Commercially available toroid winders use bobbins or shuttles to store and carry the wire through the hole of the toroid, but for less than one hundred turns they are not economically competitive with needle and thread hand winding. Yet the cost of hand winding the cores makes the cores uneconomical compared with other circuit elements.

An object of this invention is to provide a simplified wire winding apparatus for winding wire around a support, a support being herein defined to include a core, spool, or other member around which wire may be wound.

Specifically, an object of this invention is to provide a wire winding apparatus for economically winding a coil having a comparatively small number of turns around a toroid shaped support.

These and other objects of this invention are achieved in an illustrative embodiment thereof wherein the wire winding apparatus comprises a bending wheel having a coefficient of friction with respect to the wire that exceeds the coefficient of friction between the wire and the support. Positioning means hold the support in engagement with the circumferential surface of the bending wheel, the support extending transversely to the plane of the bending wheel. Feeding means feed the wire between the contiguous surfaces of the support and the bending wheel at a particular rate of speed, and driving means rotate the bending wheel at a peripheral speed exceeding the feeding speed of the wire.

A complete understanding of the invention and of these and other features and advantages thereof may be gained from consideration of the following detailed description taken in conjunction with the accompanying drawing wherein one embodiment of the invention is illustrated. It is to be expressly understood, however, that the drawing is for the purposes of illustration and description and is not to be construed as defining the limits of the invention.

In the drawing:

FIG. 1 is a front view of schematic representation of the wire winding apparatus of this invention;

FIG. 2 is a top view of the wire winding apparatus; and

FIG. 3 is a greatly enlarged view of a portion of FIG. 2.

In the detailed description that follows, reference being made to the drawing, the apparatus of this invention is described in connection with winding a wire 10 about a toroid shaped support 12. The apparatus is not, however, limited to winding wire about a support of this particular shape. The support may have any one of a variety of shapes as long as a portion of the profile of the surface about which the wire is wound is smooth and convexly curved. The term profile is herein defined as the outline of a section of a member taken at right angles with its main lines, the main lines of a member being the lines

2

extending generally parallel to the plane of a planar member, such as a toroid, and the lines extending generally parallel to the longitudinal axis of a nonplanar member, such as a cylinder.

The support 12 is mounted in a fixture 14 that holds the convexly curved portion of the support against the circumferential surface 15 of a bending wheel 16. The bending wheel 16 is formed from a material, such as rubber, that is resilient and the coefficient of friction of which with respect to the wire 10 is greater than the coefficient of friction of the wire with respect to the support 12. The support 12 is positioned with the main lines thereof extending transversely to the main lines of the bending wheel 16, and the circumferential surface 15 of the bending wheel conforms to the portion of the circumferential surface of the support in juxtaposition therewith. Thus with the support 12 having a toroid shape, the circumferential surface 15 is concave when viewed in profile. As a result of the conformance of the circumferential surface 15 of the bending wheel 16 to the portion of the support 12 in juxtaposition therewith, when the support is pressed against the circumferential surface of the bending wheel there is an elongated area of contact therebetween. This elongated area of contact will be referred to as the line of contact.

The bending wheel 16 is mounted on a shaft 18 and driving means such as the crank 20 are provided for rotating the shaft. A driving gear 22 is mounted on the shaft 18 adjacent to the bending wheel 16, and the driving gear meshes with an intermediate gear 24 that in turn meshes with a driven gear 26 mounted on a shaft 28. A first feed roller 30 is mounted on the shaft 28 alongside the driven gear 26, and a second feed roller 32 bears against the first feed roller. The number of the teeth on the driving and driven gears 22 and 26 and the diameters of the bending wheel 16 and the feed rollers 30 and 32 are selected so that the peripheral speed of the bending wheel exceeds the peripheral speed of the feed rollers.

The wire 10 is positioned between the feed rollers 30 and 32 and between the support 12 and the bending wheel 16, and when the crank 20 is rotated in a clockwise direction, the feed rollers and the bending wheel advance the wire from a spool 34. The bending wheel 16 acts to advance the wire 10 at a faster rate of speed than the feed rollers 30 and 32, but the coefficient of friction between the feed rollers and the wire, and the normal force of the rollers against the wire are such that the friction between the rollers and the wire exceeds the friction between the wire and the bending wheel. The peripheral speed of the feed rollers 30 and 32 is therefore determinative of the rate of feed of the wire 10, and the bending wheel 16 moves relative to the wire.

The bending wheel 16 maintains the wire 10 between it and the feed rollers 30 and 32 under tension and thereby acts to remove any curvature in the wire due to its having been coiled around the spool 34. In addition the bending wheel 16 presses the wire 10 against the smooth rounded surface of the support 12 and imparts a curvature to the wire that is similar to the curvature of the support. As a result, the end of the wire 10 coils around the support 12, moving through the hole thereof and back into engagement with the bending wheel 16. The bending wheel 16 directs the end of the wire 10 between it and the support 12 and because the coefficient of friction between the bending wheel and the wire is greater than the coefficient of friction between the wire and the support and because the peripheral speed of the bending wheel exceeds the rate of feed of the wire, the bending wheel pulls the wire into a tight coil around the support and again presses the wire against the curved surface of the support to reinforce the desired curvature in the wire.

Furthermore, the support 12 is located with respect to the bending wheel 16 so that the line of contact between the support 12 and the bending wheel 16 extends obliquely to the direction of movement of the bending wheel. With this arrangement the bending wheel, besides acting to tighten the turns of wire 10 around the support, also acts to direct the wire toward the point of contact between the support and the bending wheel that is farthest forward in the direction of movement of the bending wheel.

With a toroid shaped support 12 positioned as shown in FIG. 2, that is, with the plane of the support extending perpendicularly to the plane of the bending wheel 16 and inclined rearwardly to the direction of movement of the bending wheel 16, the line of contact between the support and the bending wheel is an arc shown in FIG. 3, the center A of which is farther forward in the direction of movement of the bending wheel than the ends B. Thus the portion of the arc on either side of the center A extends obliquely to the direction of movement of the bending wheel 16, and wire 10 when fed from either end B of the line of contact advances toward the center.

This is so because the force F exerted on the wire 10 by the bending wheel 16 acts in the direction of movement of the bending wheel and when the line of contact extends obliquely to this direction of movement, this force can be broken into two components. One component f_1 extends normal to the line of contact in the general direction of movement of the bending wheel 16, and this component acts to tighten the wire 10 around the support 12. The other component f_2 extends along the line of contact in the direction of the forwardmost point thereon, and this component acts to move the wire 10 toward this forwardmost point.

The relative strengths of the force f_1 acting to tighten the wire 10 around the support 12 and the force f_2 acting to move the wire toward the forwardmost point essentially depends on two parameters. The first parameter is the orientation of the line of contact between support 12 and the bending wheel 16 with respect to the direction of movement of the bending wheel. Thus, if the toroid shaped support 12 is not inclined rearwardly to the direction of movement of the bending wheel 16 as shown in FIG. 2, but instead is positioned with the plane thereof extending perpendicular to the direction of movement of the bending wheel, the line of contact is a straight line. Furthermore, if the plane of the toroid shaped support 12 extends perpendicular to the plane of the bending wheel 16, the line of contact extends perpendicular to the direction of movement of the bending wheel. In this situation the entire force F exerted on the wire 10 by the bending wheel 16 acts to tighten the wire around the support 12, and there is no component f_2 acting to move the wire along the support 12. As a result, the wire is wound in a random fashion with the turns extending in all directions and over and under one another rather than extending side by side in a continuous helical coil.

Conversely, if the support member 12 is positioned with respect to the bending wheel 16 so that the line of contact therebetween extends parallel to the direction of movement of the bending wheel, the entire force F exerted on the wire 10 acts to move the wire along the support 12. There is no component f_1 acting to coil the wire around the support, and as a result no coiling occurs.

From these two examples it can be deduced that as the line of contact moves from a position that is nearly perpendicular to the direction of movement of the bending wheel 16 to a position that is nearly parallel to the direction of movement of the bending wheel, the force f_1 acting to tighten the wire 10 around the support decreases while the force f_2 acting to move the wire toward the forwardmost point increases.

The second parameter is the configuration of the support 12 at the place the wire 10 is wound around the support. If the support 12 has a uniform cross section at the place the wire 10 is wound, the tightening force is

normal to the surface of the support and the force acts only to tighten the coil. If the support 12 is tapered at the place the wire 10 is wound, the tightening force is not normal to the surface of the support and part of the tightening force acts to move the coil toward the portion of reduced cross section.

The parameters are selected so that both the force f_1 acting to tighten the wire 10 around the support 12 and the force f_2 acting to move the wire 10 toward the forwardmost point are present and the latter force is not excessive. Then, with each passage of the wire 10 around the support 12, succeeding turns lie side by side and do not jump over one another, and if the length of the line of contact is at least as great as the length of the coil desired, each turn remains in contact with the bending wheel 16 whereby continuous control may be exercised on each turn. As succeeding turns build up behind the initial turn, the forces acting on the coil as a whole tend to position the center of the coil at the forwardmost point. Consequently, the distance along the line of contact between the forwardmost point of contact and the rearwardmost point of contact is advantageously at least as great as half the length of the desired coil.

The feed rolls 30 and 32 are advantageously used to measure the length of wire fed between the bending wheel 16 and the support 12, and by knowing the length of wire per turn, the feed rolls can be employed to determine when the desired number of turns have been wound on the support.

When the desired number of turns have been completed, the end of the wire 10 is retrieved by a pickoff wheel 36 formed from a material having a coefficient of friction with respect to the wire that exceeds the coefficient of friction of the wire with respect to the support 12. The pickoff wheel 36 is mounted on a shaft 40, the shaft 40 being secured to a lever 42 that pivots about a pin 44. By moving the lever 42 in a counterclockwise direction, the pickoff wheel 36 is moved into engagement with both the wire on the support 12 and the circumferential surface 15 of the bending wheel 16. The clockwise movement of the bending wheel 16 rotates the pickoff wheel 36 in a counterclockwise direction which is contrary to the direction of movement of the wire 10 around the support 12. Thus when the end of the wire 10 moves into engagement with the pickoff wheel 36, it is deflected from the support 12 and directed between the pickoff wheel and the bending wheel 16. The pickoff wheel 36 rotates at the same peripheral speed as the bending wheel 16 and, therefore it rotates at a higher peripheral speed than the rate of feed of the wire 10. Tension is thereby maintained on the end of the wire 10 and the coil around the support 12 is kept tight. This end of the wire 10 provides one lead for the coil, the other lead being provided by severing the wire 10 intermediate the feed rollers 30 and 32 and the bending wheel 16.

What is claimed is:

1. Apparatus for winding wire around a support having a portion of the profile of the surface about which the wire is wound smooth and convexly curved, the apparatus comprising:

- a bending member having a coefficient of friction with respect to the wire that exceeds the coefficient of friction between the wire and the support;
- means for moving the bending member at a particular peripheral speed in a particular direction;
- means for positioning the periphery of the bending member and the curved portion of the support in engagement with one another, the contiguous surfaces thereof conforming to one another to provide a common line of contact therebetween a portion of which extends obliquely to the direction of movement of the bending member; and
- means for advancing the wire between the contiguous surfaces of the support and the bending member at

5

a rate of speed below the peripheral speed of the bending member, the wire being fed between the support and the bending member at a point along the line of contact that is rearward to the direction of movement of the bending member.

2. A wire winding apparatus as in claim 1 further including means for retrieving the end of the wire comprising a pickoff member having a coefficient of friction with respect to the wire that exceeds the coefficient of friction of the wire with respect to the support, means for positioning the pickoff member in engagement with the wire wound about the support, the pickoff member moving contrary to the direction of movement of the wire around the support at a peripheral speed exceeding

6

the speed at which the wire is advanced between the support and the bending member.

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