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WIRE COILING

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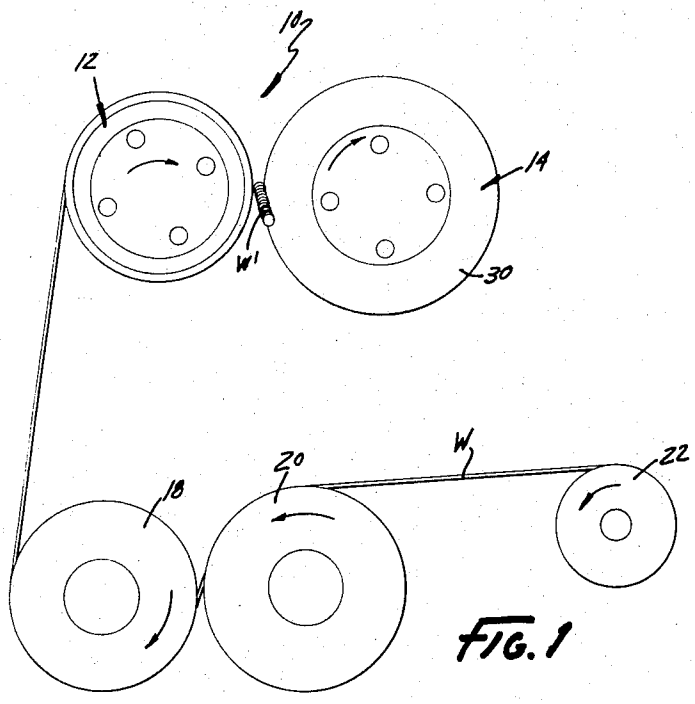


FIG. 1

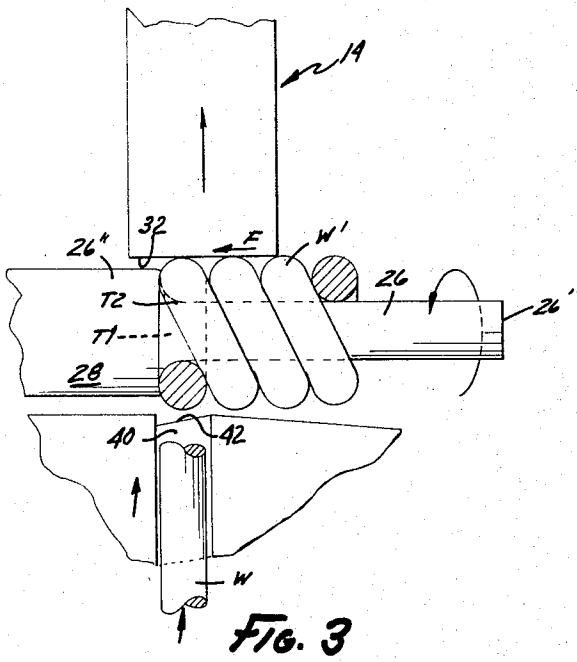


FIG. 3

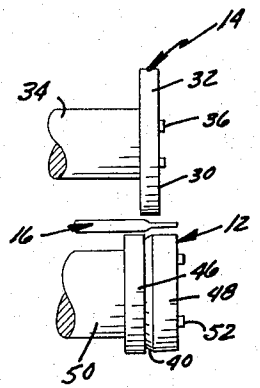


FIG. 2

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WIRE COILING

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ABSTRACT OF THE DISCLOSURE

Method and associated apparatus for coiling wire into resistance coils, for example, by coiling the wire around a spinning mandrel straddled by two revolving work rolls, the wire being fed around the periphery of one work roll at a potential linear feed rate greater than the actual linear rate of coiling, coupled with a controlled wire slippage on said one feed roll, to assure sufficient feed without over feed and without requiring the mandrel to pull the wire, the wire being advanced to the mandrel in a plane normal to the mandrel axis from a special groove in the one work roll periphery, and then turned to the helix angle against a special shoulder on the spinning mandrel.

This invention relates to a method and apparatus for winding wire into a helical coil, and more particularly to a method of winding a coil of wire into a uniform wire helix.

The coiling of wire into a uniform, pattern-free helix has been a problem for over three decades. This is particularly true of the so-called "fine" range of resistance wire, i.e. about 0.003 inch to 0.010 inch in diameter.

Conventional wire coiling is practiced by cinching the lead turn of wire onto a spinning mandrel, and then having the mandrel pull the wire onto and around the spinning mandrel as the wire is guided in a path in line with the end of the helical pattern. The wire is, of course, pulled toward and onto the mandrel at the same rate as it is turned into a coil. Coils formed according to these conventional techniques are known by those in the field to vary considerably in non-uniformity. They commonly exhibit a repeat pattern of helix angles over the coil length, with this defect being amplified in effect, in fine wire sizes. The operating characteristics, particularly electrical characteristics, of these coils vary considerably, to present substantial problems to users of the coils. These variations in characteristics result from tension on the wire, pressure on the wire, ironing or crowding when the coil is formed. Any of these actions causes distortion that prevents any hope of coiling uniformity.

It is an object of this invention to provide a novel method of winding wire into a relatively uniform helical coil.

Another object of this invention is to provide a unique new method of helically coiling wire in a manner which is in contradiction to the accepted principles of coiling, but in so doing, obtains a remarkably superior uniformity in the helix. The method even obtains greatly superior uniformity in fine wire coils, repeatedly, smoothly and dependably.

Another object of this invention is to provide a method of helically coiling wire without binding the lead turn on the mandrel.

Another object of this invention is to provide a method of helically coiling wire without pulling the wire in tension onto the mandrel.

Another object of this invention is to provide a method of coiling wire into a helix of superior uniformity by not guiding the wire in a diagonal line aligned with the helical turns of the wire, but rather by guiding it in a plane

which is normal to the axis of the mandrel, and therefore, angularly offset from the angle of the helix.

Another object of this invention is to provide novel wire forming equipment which enables coils of superior uniformity and generally pattern-free characteristics to be formed.

Another object of this invention is to provide a wire coiling apparatus which is relatively simple in construction, and which dependably and repeatedly achieves superior winding uniformity in the wire helix, whether the wire is fine or otherwise.

These and several other objects of this invention will become apparent upon studying the following specification in conjunction with the drawings in which:

FIG. 1 is a front elevational view at a small angle of the forming apparatus of this invention;

FIG. 2 is a plan view of the apparatus in FIG. 1; and

FIG. 3 is a greatly enlarged, fragmentary, plan view of the apparatus in FIG. 2.

Referring now specifically to the drawings, the coiling apparatus **10** includes as the main components a driven front work roll **12**, a driven rear work roll **14**, and a mandrel **16** between the forming rolls. It also includes a pair of wire guide idlers **18** and **20**, and a wire reel **22**.

The small diameter mandrel **16** is a spinning mandrel or arbor driven from a suitable power supply means. Its outer free end comprises an elongated, cylindrical forming portion **26** of a diameter equal to approximately the inside diameter desired of the coil of wire formed thereon. It includes a discharge end **26'** on one end of the cylindrical forming portion, and an annular, radially extending forming shoulder **26''** on the opposite end of the cylindrical portion. This forming shoulder has a concave peripheral shoulder edge between cylindrical portion **26** and the enlarged diameter portion **28** of the arbor. The concavity is curved to match the peripheral or circumferential curvature of the wire to be formed thereon. The mandrel is specifically selected to suit the wire size therefor. The larger diameter portion next to the concave shoulder has a smaller diameter than the diameter of the smaller portion plus twice the wire diameter, so that the wire projects beyond it to be contacted by the back work roll **14**.

The back work roll assembly **14** includes a revolving disc **30** having a peripheral, wire engaging, friction surface **32**. At least the surface is formed of a material having a high coefficient of friction, e.g. rubber. It is mounted to the end of a suitable powered driving shaft **34** as by Allen screws **36**. The flat cylindrical peripheral friction drive surface **32** is immediately adjacent mandrel **16**, particularly shoulder portion **26''** thereof, and overlapping a segment of cylindrical forming portion **26**. During operation, it is revolved in a rotational direction opposite to that in which the arbor is revolved, in order to have its peripheral surface move in the same direction as the adjacent portion of the peripheral surface of the mandrel.

The front work roll **12** includes a peripheral surface having a special peripheral groove **40** therearound. This groove includes a tapered bottom surface **42** (FIG. 3) facing the concave mandrel shoulder edge at an acute angle. The tapered surface is slightly wider than the wire diameter. The edge of this groove is aligned with the concave edge of the shoulder, with the tapered surface being immediately adjacent thereto, to feed the wire W directly against the concave shoulder, holding the wire against this shoulder edge during the first 180° (½ turn) of the forming operation around the arbor.

This work roll **12** may be formed of a pair of elements **46** and **48**, independently machined, and secured together and to the end of drive shaft **50** as by Allen screws **52**.

Method

In practicing the method of this invention, the wire W is unwound from a suitable spool of wire 22 supported to freely revolve. It preferably passes over a pair of idler rolls 18 and 20 which may be located in a lubricant both so that the wire will be coated with lubricant prior to forming. These steps are conventional.

The wire then is handled in the novel manner. Specifically, instead of the wire having the first turn or so cinched on the mandrel and being pulled directly onto the spinning mandrel by the revolving mandrel, it rather is positively fed up over the surface of the work roll 12 for about 180°. It is fed into the peripheral groove 40 around this work roll. It travels up and over the work roll in frictional engagement therewith down along the adjacent side of the mandrel. The frictional engagement of the wire over a substantial area of the driven roll causes the wire to be positively fed to the mandrel. Extensive experimentation shows that the positive infeeding of the wire eliminates many harmful stresses on the wire that tends to cause non-uniformity. It has been found necessary to prevent cinching of the coils, even the first coil, on the arbor, because a cinched coil simply cannot be uniformly advanced off the end of the arbor.

In fact, it was found that the wire should not only be positively fed to the arbor at the rate at which it is turned into and removed as a coil, but rate of infeed should be self-adjusting in rate to just exactly equal the rate of take up needed on the forming arbor.

This desired automatic feed compensation is achieved by feeding the wire over the front work roll.

This good contact provides an "over-feed" condition which assures the mandrel of having sufficient wire to prevent the mandrel from pulling on the wire in tension in order to obtain enough for the coiling operation. The over-feed condition, however, does not cause the wire to be in excess so as to cause difficulties, since, as soon as it occurs, the slackening of wire on roll 12 causes a limited slippage to then occur between feed roll 12 and the wire so that the actual linear rate of movement of the wire around this roll and into the mandrel is exactly the same as the linear rate movement of the wire W' around the mandrel and off its discharge end. In operation, therefore, it has been found that the wire "floats in equilibrium," so to speak, without tension and without noticeable slack. The arbor is then purely a "forming member," and does not comprise a pulling medium. The coil is thus no longer a cinched coil, but a free running coil. This promotes a remarkable improvement in coil uniformity. These principles of operation are used in combination with another one that pertains to the constant half-turn of wire being deformed from the front feed roll onto the mandrel. This pertains to the alignment of the feed roll groove to the forming shoulder on the mandrel. Specifically, since groove 40 is directly aligned with the concave shoulder edge on the mandrel, and since the groove surface 42 is tapered to face toward this concave shoulder edge, the wire is also held against this shoulder edge for a fraction of a turn, i.e. about one-half of the first turn formed, or relatively, of the last turn in the coil.

The wire W is thus held for the first one-half turn of coil forming (i.e. the last one-half turn on the coil) in a plane which is normal to the spin axis of the mandrel (as shown in FIG. 3). After the wire has moved through the one-half turn T1 down and around the bottom side of the mandrel, held against the concave shoulder edge, it then must be off-set in the next one-half turn T2 up and over the top of the mandrel surface. This occurs by the second one-half turn actually "rolling off" the first one-half turn being subsequently formed. In other words, the smooth wire surface itself of the half-turn being then formed rolls the adjacent wire surface over an amount equal to the diameter of the wire (as can be seen by FIG. 3), to then initiate the helical angle of the wire in

this second one-half turn T–2. As can be understood, the "shifting" force between the adjacent contacting wire portions necessary to initiate this helical angle not only starts the helix forming, but also assures that the first one-half turn T–1 will always be tightly held against the mandrel shoulder edge during its first one-half turn. The wire therefore "captures" itself against the special shoulder, with the aid of the special tapered surface in the groove of the front feed roll.

It will be noted that the wire is "covered" or controlled on both sides of the mandrel since tapered surface 42 of the groove 40 holds the wire against the shoulder on one side, while the peripheral advancing surface 32 on back feed roll 14 captures it or covers it on the backside. This rear friction roll not only advances the wire in its circumferential movement, but also retains the coil from advancing uncontrollably in its axial discharge direction. It has a retarding force toward shoulder 26" as indicated by the arrow F in FIG. 3. The wire is thus completely controlled in a captured condition by the front roll, rear roll, and mandrel.

It has been found that the peripheral speeds of the front feed-in and wire guide rolls and the back circumferentially advancing and axially holding roll can be the same to have regulated "free floating" of the wire coil on the mandrel. With some wire sizes or types, a greater percentage of over-feed and slippage may be desired. If so, the front feed-in and guide roll can be rotated at a greater selected peripheral speed than that of the mandrel and the rear advancing and holding roll.

It has been found with extensive experimentation of the apparatus and method that excellent uniformity of coiling results, even with fine size wire. The principles are unorthodox, but extremely effective.

In practice, it may sometimes be desirable to utilize steel rolls, front and back, instead of rubber surfaces. Also, the front roll could be used for coiling pressure like the rear roll, as well as for feeding and guiding. Moreover, spaced windings could be achieved by inserting a spacer, such as clock spring steel disc, on the rolls to run between the turns of wire.

The terms "front" and "back" are obviously relative. These were used herein for convenience to designate particular rolls with particular functions and should not be interpreted in a limiting manner since obviously the functions thereof could be exchanged, or the roll could be above and below, or otherwise generally oppositely arranged astraddle the mandrel.

In view of the breadth of the concepts presented, the invention is intended to be limited only by the scope of the appended claims, and the reasonable equivalents thereto.

I claim:

1. A method of winding wire into a helical coil by the use of a spinning mandrel and two mandrel straddling, driven, revolving work rolls, comprising the steps of: spinning the mandrel, positively feeding the wire around the periphery of one of said revolving work rolls to said spinning mandrel, and coiling said wire around said mandrel with frictional engagement thereof by the second revolving work roll while retaining said coil free from a cinched condition on said mandrel.

2. A method of coiling wire on a spinning mandrel comprising the steps of: spinning the mandrel, while coiling the wire around said mandrel at a constant rate of linear wire movement, simultaneously advancing wire to said spinning mandrel at a linear speed greater than said coiling rate while also allowing slippage thereof to prevent uncontrolled over-feed, thereby preventing the wire from binding on said mandrel and from being pulled by said mandrel.

3. A method of coiling wire on a spinning mandrel straddled by front and back revolving work rolls, comprising the steps of: spinning the mandrel; continuously coiling the wire at a specific linear rate onto said mandrel

by engagement of said back work roll with the wire on said mandrel; continuously feeding the wire around a portion of said front work roll to said mandrel while revolving said front work roll at a peripheral speed greater than the linear rate of coiling onto said mandrel to cause an over-feed condition of said wire, while also allowing slippage of said wire on said front work roll to compensate for said over-feed condition, to prevent said wire from binding on said mandrel while being coiled thereon.

4. A method of coiling wire on a spinning mandrel, comprising the steps of: spinning the mandrel and coiling the wire thereon without allowing the wire to bind on the mandrel while frictionally squeezing a revolving work roll against said wire to govern its axial position on said mandrel while advancing its linear position as it winds; and simultaneously positively advancing wire to said mandrel while preventing said wire from binding on said mandrel, and preventing said wire from being pulled by said spinning mandrel.

5. A method of coiling wire on a spinning mandrel comprising the steps of: spinning the mandrel; feeding wire to said mandrel and continuously winding said wire on said spinning mandrel while continuously holding the wire in the last one-half turn of the coil in a plane normal to the mandrel spinning axis, while continuously offsetting the next to the last one-half turn an amount equal to the thickness of the wire by rolling it off the wire in the last one-half turn to form the helix angle.

6. A method of coiling wire on a spinning mandrel straddled by first and second revolving work rolls, comprising the simultaneous continuous steps of: spinning said mandrel; revolving said second work roll against the wire on the mandrel to wind it; feeding said wire around said first work roll while revolving said first work roll at a peripheral speed greater than the linear rate of winding to create an over-feed condition in the wire, while allowing slippage of said wire on said first work roll to automatically accommodate the over-feed differential; holding the wire in the last one-half turn being formed in the coil in a plane normal to the mandrel spin axis, and offsetting the next to the last one-half turn an amount equal to the wire thickness by rolling it off the wire in the last one-half turn.

7. A method of coiling wire on a spinning mandrel having a peripheral shoulder and straddled by a peripherally grooved driven first roll and a wire engaging driven second roll, comprising the steps of: continuously spinning the mandrel and rotatably driving the rolls while maintaining the groove of said first roll in alignment adjacent the shoulder of said mandrel; positively infeeding the wire around a portion said driven grooved roll by frictional relation therebetween while holding the wire, by said groove and shoulder, in the last one-half turn of wire coil, in a plane normal to the mandrel spin axis, while offsetting the next to the last one-half turn.

8. A method of coiling wire on a spinning mandrel having a peripheral shoulder and straddled by a peripherally grooved driven first roll and a wire engaging driven second roll, comprising the steps of: continuously spinning the mandrel and rotatably driving the rolls while

maintaining the groove of said first roll in alignment adjacent the shoulder of said mandrel; positively infeeding the wire around a portion of said driven grooved roll by frictional relation therebetween while holding the wire against said shoulder by said groove on one side, and by engagement of said second roll on the opposite side, for the last one-half turn of wire coil, in a plane normal to the mandrel spin axis, while offsetting the next to the last one-half turn.

9. A method of coiling wire on a spinning mandrel straddled by first and second revolving work rolls, comprising the simultaneous continuous steps of: spinning said mandrel; revolving said second work roll against the wire on the mandrel to wind it; feeding said wire around said first work roll while revolving said first work roll at a peripheral speed greater than the linear rate of winding to create an over-feed condition in the wire, while allowing slippage of said wire on said first work roll to automatically accommodate the over-feed differential; maintaining the groove of said first roll in alignment adjacent the shoulder of said mandrel against said shoulder by said groove on one side, and by engagement of said second roll on the opposite side, for the last one-half turn of wire coil, in a plane normal to the mandrel spin axis, while offsetting the next to the last one-half turn an amount equal to the wire thickness by rolling it off the wire in the last one-half turn.

10. Wire coiling apparatus comprising: a spinning mandrel and a pair of revolving straddling first and second work rolls adjacent said mandrel; said mandrel having an elongated cylindrical coil forming portion and discharge end, and a radial, peripheral wire-abutting shoulder at the end of said portion opposite said discharge end; said second roll having a peripheral wire engaging surface; and said first roll having a peripheral wire feed and guide groove in a plane normal to the mandrel spin axis and aligned adjacent said mandrel shoulder to feed the wire to said forming portion while holding it against said shoulder in said plane.

11. Wire coiling apparatus comprising: a forming mandrel having an elongated, cylindrical, forming portion with a coil discharge end and a radially projecting peripheral shoulder at the opposite end; said shoulder having a concave wire receiving edge adjacent said portion; and a wire feeding roll adjacent said mandrel, having a wire receiving peripheral groove aligned with said concave shoulder edge, and said groove having a tapered surface facing said shoulder to hold said wire against said shoulder edge.

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