April 20, 1965 J. M. DREES ETAL 3,179,347

ADAPTER FOR HELIX WINDING APPARATUS

Original Filed Sept. 25, 1961 3 Sheets-Sheet 1

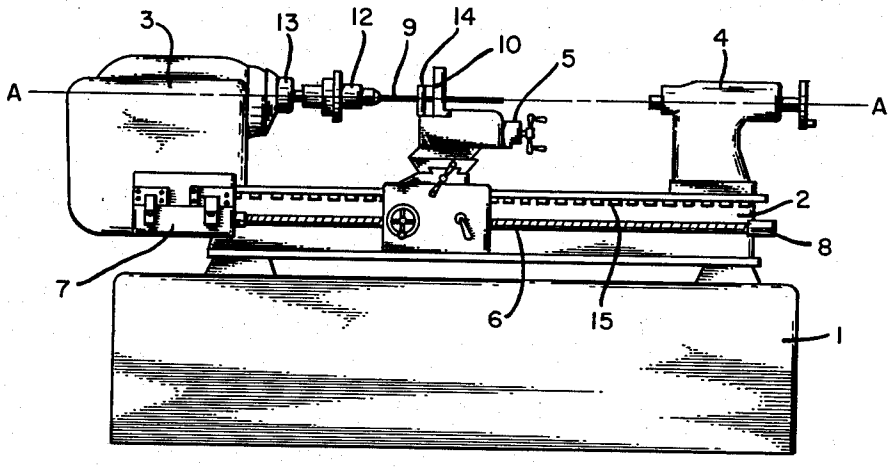

FIG-1

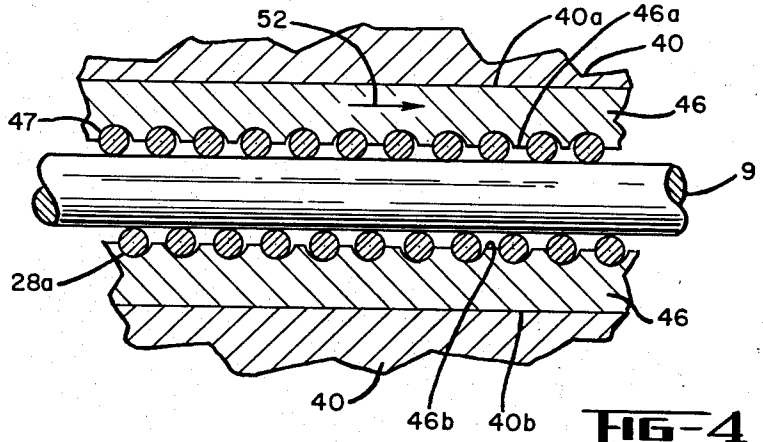

FIG-4

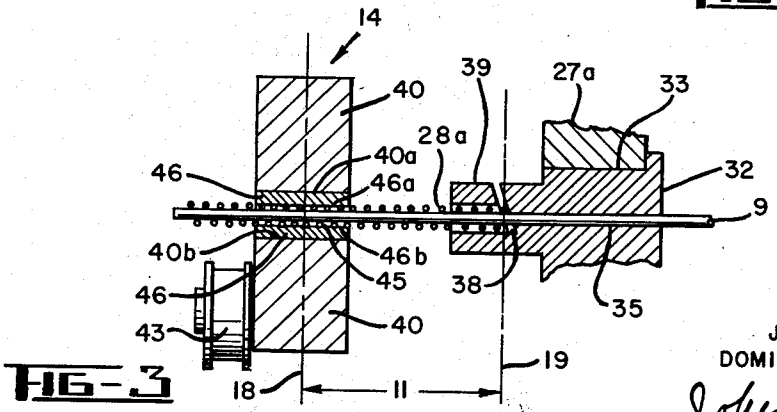

FIG-3

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ADAPTER FOR HELIX WINDING APPARATUS

Original Filed Sept. 25, 1961

3 Sheets-Sheet 2

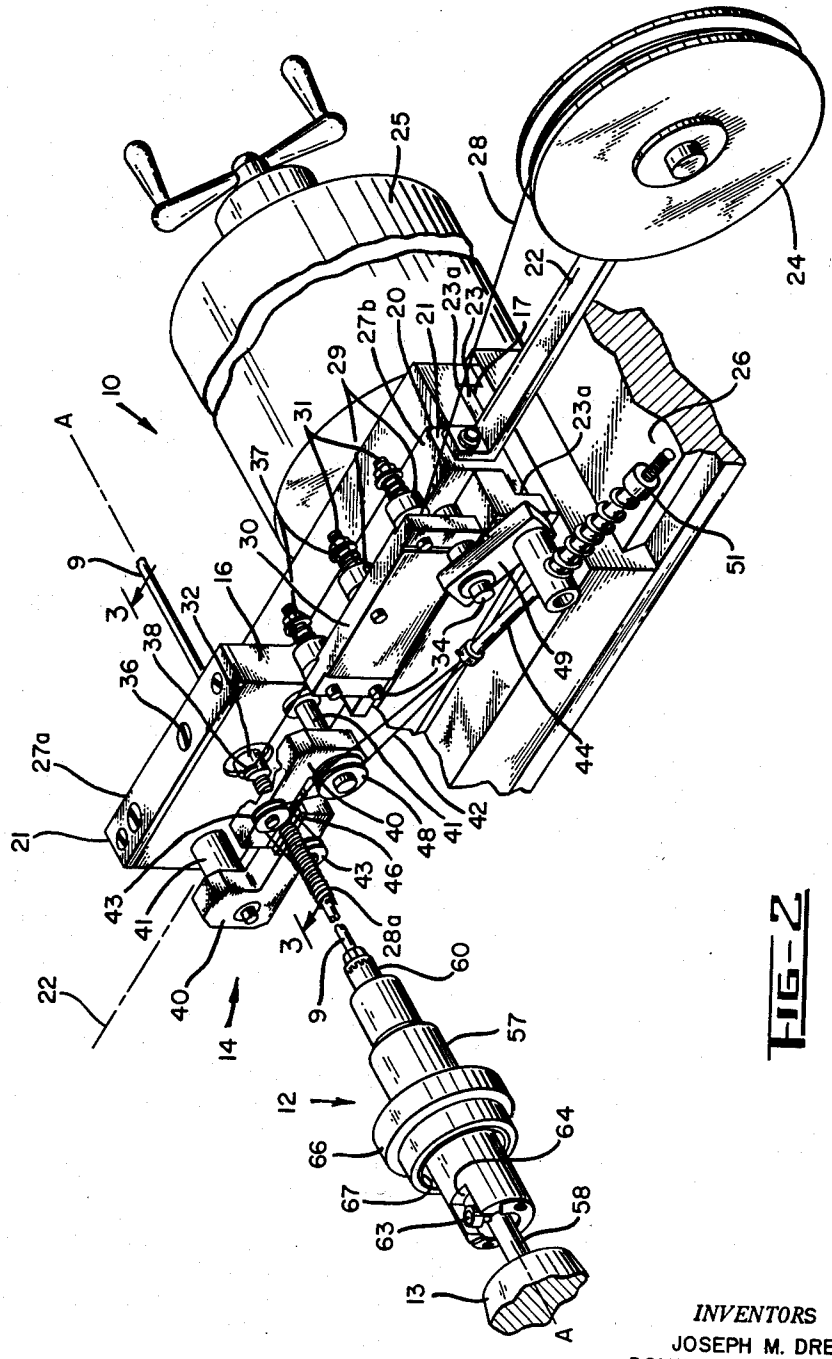

FIG-2

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ADAPTER FOR HELIX WINDING APPARATUS

Original Filed Sept. 25, 1961 3 Sheets-Sheet 3

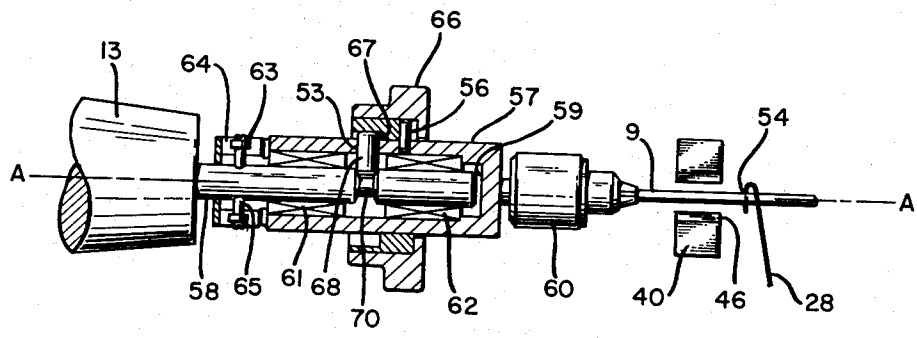

FIG-5

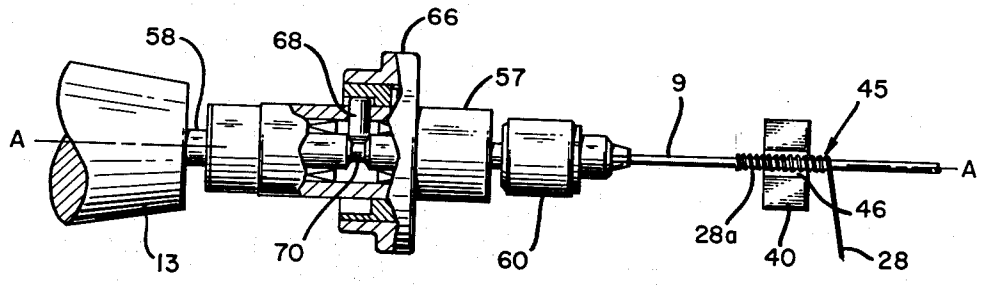

FIG-6

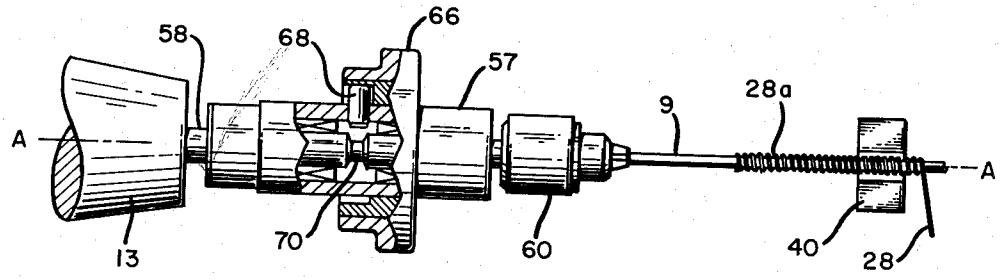

FIG-7

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United States Patent Office 3,179,347 Patented Apr. 20, 1965

3,179,347

ADAPTER FOR HELIX WINDING APPARATUS

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Continuation of application Ser. No. 140,298, Sept. 25, 1961. This application Aug. 6, 1962, Ser. No. 217,237
9 Claims. (Cl. 242—9)

This application is a continuation of application, Serial No. 140,298, filed September 25, 1961, now abandoned.

This invention relates to coil winding apparatus and more particularly to an adapter used with a conventional lathe for winding fine wire into coils or helices having precise spacing between turns.

A traveling wave tube employs a helix formed of wire to propagate an electromagnetic signal in phase with an adjacently located electron beam. As the beam travels along the axis of symmetry of the helix, energy is exchanged between the beam and the signal such that amplification of the latter occurs.

However, experience has shown that helices wound by usual methods, e.g., on lathes having gear drives, do not provide satisfactory operation of the traveling wave tubes into which they are incorporated. It is believed this unsatisfactory operation of the tube results from slight variations in the spacing between turns of the helix introduced during its fabrication by errors in the spacing of the gear teeth of the lathe. These variations, imperceptible by usual precision gauging methods, cause the axial velocity of the signal residing on the helix to vary non-uniformly with respect to the electron beam traveling adjacent the helix. The result is non-uniform interaction of the beam and the signal and corresponding low amplification of the signal, or in the extreme, total tube inoperativeness.

It is the object of the present invention to provide an adapter to a conventional lathe which facilitates the winding of the coils or helices having a precise and uniform turn-to-turn spacing.

Another object of the invention is to provide an adapter to a lathe for winding coils or helices from wire having small diameters.

Another object of the invention is to provide an adapter of the class indicated in which the spacing between turns of the coil or helix is readily and conveniently adjustable.

Another object of the present invention is to provide an adapter of the class indicated for winding fragile coils or helices wherein the spacing between turns varies in accordance with a pre-determined function from one end of the coil to the other.

These and other objects of the invention will become apparent from the following description of a preferred embodiment, reference being had to the accompanying drawings in which:

FIGURE 1 is a front elevation view of a coil winder comprising a lathe and adapter constructed in accordance with the invention;

FIGURE 2 is an isometric projection of an adapter comprising the invention mounted on a portion of the mounting carriage of the lathe;

FIGURE 3 is a cross-sectional view, taken along plane 3—3 of FIGURE 2, illustrating parts of the wire feed assembly of the adapter;

FIGURE 4 is an enlarged view of a portion of FIGURE 3 illustrating the relationship of the turns of the helix and the clamping mechanism of the wire feed assembly, and

FIGURES 5 through 7 inclusive are schematic diagrams illustrating the operation of the adapter mechanism.

Briefly, the apparatus comprising the invention employs

a standard gear-train lathe for supporting and driving a coil winding mandrel and its mounting assembly in rotation, and on which a carriage is mounted, as by a lead screw, for movement parallel to the mandrel. As the carriage traverses the length of the mandrel, a helix or coil is laid down by the operation of a wire feed assembly mounted to the carriage. This assembly includes a set of rectangular nylon bearings having a series of grooves formed on contacting surfaces to engage the turns of the formed helix. As variations occur in the spacing of the gear train or lead screw of the lathe, the wire feed assembly is moved non-uniformly relative to the mandrel. However, this movement is compensated by instantaneous axial movement of the rotating mandrel and its chuck assembly relative to the bed of the lathe provided by the engagement of the turns of the helix with the side walls of the grooves formed in the support bearings. The axial velocity of the wire feed assembly relative to the mandrel thus remains constant during winding operations to provide helices having precise spacing between turns.

Referring to the drawings, particularly to FIGURES 1 and 2, an adapter comprising the invention is preferably mounted on a lathe having a base **1** on which is mounted bed **2**. Bed **2** supports lathe head stock assembly **3** at one end thereof, a tail stock assembly **4** at the other end, and intermediately positioned carriage assembly **5**.

The carriage assembly **5** is slideably supported on the bed **2** and engages rack **15** at its upper portion and lead screw **6** at its base. These connections are entirely conventional and are omitted from the drawings in the interest of clarity. Lead screw **6**, in turn, is journaled to gear feed assembly **7** at one end and to bearing **8** at the other end.

The helix or coil comprising relatively small diameter wire, preferably of tungsten, is wound by rotating coil winding mandrel **9** about axis A—A of the apparatus as wire feed assembly **10** attached to carriage **5** moves along a path parallel with the mandrel. The rate of such axial movement as well as the angular velocity of the mandrel are critical to the formation of precise helices and have heretofore been dependent on the individual spacing of the teeth of the lead screw **6**, rack **15** and the gear train connecting the rotating mandrel with its driving means. Any variations in gear teeth spacing change these rates perceptibly and, in turn, the turn-to-turn spacing of the helix being laid down.

These variations, however, are compensated by the adapter comprising the invention such that the rate of travel of the wire feed assembly **10** and carriage **5** relative to the mandrel **9** are relatively constant during winding operations. Specifically, as explained in detail below, the mandrel **9** is attached to a portion of chuck assembly **12** which is slideable relative to the bed of the lathe, thereby facilitating movement of the mandrel along the axis A—A of the assembly. The chuck **12**, in turn, is secured to the collet **13** of the spindle of the head stock to transmit rotary movement to the mandrel.

At locations remote from the collet **13**, clamping mechanism **14** comprising a pair of symmetrically located arms **40** (FIGURE 2) attached to and rotatable with wire feed assembly **10** engages with the turns of the formed helix to secure the mandrel relative to the wire feed assembly **10**. As variations in the spacing of the gear teeth occur, the erratic movement of assembly **10** is transmitted by arms **40** to mandrel **9**, causing the latter to respond with movement relative to the bed of the lathe. Thus the axial distance **11** between the center lines **18** and **19** of the clamped portion of the helix and the wire feed assembly **10**, respectively, as shown in FIGURE 3, is held relatively constant during the winding

operation. The result is the formation of a helix having precise spacing between turns.

To summarize the description this far, a motor (not shown) drives lead screw 6 and chuck assembly 12 in rotational movement through a conventional gear train as wire feed assembly 10 attached to carriage 5 moves along a path parallel with the mandrel depositing a helix or coil therealong. By virtue of the interaction of the wire feed assembly 10 with the chuck assembly 12, the variation in spacing of the gear teeth of the driving means of the assembly are averaged and the turn-to-turn spacing of the helix thus deposited is constant.

Referring to FIGURE 2, wire feed assembly 10 comprises a center boom 20 located adjacent the mandrel 9 for supporting the wire from which the helix is wound and a clamping mechanism 14 which engages the turns of the formed helix for maintaining the mandrel 9 in a fixed axial relationship relative to the boom 20. Boom 20 includes a base 23 of rectangular cross section and enlarged portion 27*a* and reduced portion 27*b*, separated by step 16, formed near its forward and rearward ends, respectively. The terms "inner" and "forward" refer to the end of the boom 20 adjacent the axis A—A of the assembly, while the terms "outer" and "rearward" designate the opposite end of the boom. Support for portions 27*a* and 27*b* is achieved by the attachment of the lower surface of portion 27*b* to base 23, the assembly being oriented such that axis 22, defined by the ends 21 of the portions 27*a* and 27*b*, is at right angles to the axis A—A of the assembly.

Attachment of the base 23 to the carriage 5 is provided by the engagement of the peripheral sides 23*a* of the base with T-shaped opening 17 in conventional lathe post 25. Post 25, in turn, is attached to post 26, these parts being journaled to rack and pinion assemblies (not shown) to facilitate alignment of the assembly 10 in a plane adjacent to the axis of the mandrel 9.

Adjacent end 21 of reduced portion 27*b*, wire reel 24 containing wire 28 of the type from which coil or helix 28*a* is to be wound is mounted for rotation about an axis parallel to the axis A—A of the assembly. Wire 28 is fed from the reel, past the ends of spring-loaded rollers 29 mounted to support member 30, and thereafter to guide bushing 32, the latter secured, as by set screw 36, within an opening 33 (FIGURE 3) in the enlarged portion 27*a* of the boom 20.

In the particular embodiment illustrated, support members 20 and 30 are fabricated from blanks having rectangular cross-sections and attached to one another by pins 34, but could be made integral as by casting. It is also to be noted that these parts are spatially located in a plane such that the wire 28 being fed between the ends of rollers 29 and adjacent surface of support 30 is not unduly tensioned during forming of the helix. Frictional drag on the wire is increased or decreased by changes in the active length of the springs abutting rollers 29, as by rotation of nuts 37.

Referring to FIGURE 3, guide bushing 32 has a stepped-cylindrical shape, and comprises a wall 35 extending parallel with axis A—A and defining an opening through which mandrel 9 extends, and a slot 38 positioned in its cut-away reduced portion 39. Slot 38 is located in a plane approximately mid-way between the boom 20 and support 30 and positions wire 28 relative to the mandrel 9 as the coil or helix is laid down.

Attached to the enlarged portion 27*a* of the boom 20 is helix clamping mechanism 14 comprising a pair of symmetrically located clamping arms 40. These arms are rectangular in cross-section and are pivotally mounted on extension pins 41 to facilitate engagement of bearings 46 with a portion of turns of the helix formed about mandrel 9. These bearings 46 are mounted on the surfaces 40*a* and 40*b* (FIGURE 3) of arms 40 and are preferably made of nylon and thus have a low coefficient of friction, to allow indentations or grooves to be formed

in their adjacent surfaces as rotation of the helix occurs. In addition, the length of bearing 46 in the plane at right angles to axis A—A permits several turns of helix 28*a* to be instantaneously gripped as shown best in FIGURE 3 and for reasons explained hereinafter thus facilitates the attachment of wire feed assembly 10 to mandrel 9.

To provide movement of the arms 40 relative to axis A—A, a series of wires or cables 42 pass over tension pulleys 43 located on the surfaces of the clamping arms 40. Cables 42 are connected to actuating lever 44 mounted to crank 49 which in turn is attached to support 30. As axial movement of the wires 42 parallel with the axis 22 occurs, as by rotating crank 49 clockwise as viewed in FIGURE 2, arms 40 pivot bringing bearings 46 into engagement with the turns of helix 28*a*. Lateral movement of the cables is restrained by the grooves of the pulleys, with cable slack taken up by pulley idler 48.

In order that the magnitude of pressure exerted on the helix by arms 40 be precisely controlled, the axial position of actuating lever 44 relative to crank 49 is adjustable. For example, the axial location of the lever can be varied by changes in the throw of crank 49 or by changes in the axial location of stop nut 51 attached to a threaded end of the lever 44.

Referring to FIGURE 3, as arms 40 are pivoted relative to the axis A—A of the assembly, bearings 46 contact portion 45 of helix 28*a*. Although frictional drag is introduced by this engagement, rotational movement of the helix relative to clamping mechanism 14 is permitted because of the resilient nature of the bearing material. As the helix continues to rotate relative to the bearings 46, compressive forces exerted by arms 40 force the turns of the helix to become embedded within the bearing surfaces 46*a* and 46*b*, thereby forming a series of grooves 47 (FIGURE 4).

When this condition occurs, the axial distance 11 between center lines 18 and 19 of the clamped portion 45 of the helix 28*a* and guide bushing 32 of wire feed assembly 10, respectively, is relatively fixed. Thus as subsequent errors in the spacing of the teeth of one lead screw or the gear train for rotating movement are encountered, the turns of the helix engaging the wall of the groove cause axial travel of the mandrel 9 relative to the bed of the lathe. Such movement occurs, however, only if the mandrel is free for translational movement along the axis of the assembly relative to the bed of the lathe.

An additional reason for the provision of axial movement of the mandrel relative to the lathe bed is in order to compensate for the dynamic forces (illustrated as vector quantity 52, FIGURE 4), generated by the engagement of helix 28*a* with grooves 47. Although it would appear that grooves 47 support the turns of the helix in equilibrium, this is not the case. The initially formed turns of the helix serpentining through grooves 47 have spacing varying directly with the pitch of the teeth of the lead screw 6 and gear train of the lathe. That is, mandrel 9 is fixed relative to the bed of the lathe when the initial portion of helix is laid down and therefore cannot respond as non-uniform movement of wire feed assembly 10 occurs. Thus as the turns engage grooves 47, reactive forces are set up, the magnitude of the axial resultant of which is proportional to the total of the reactive forces parallel with the axis of the apparatus.

For example, after the mandrel has rotated one revolution, the individual turns of the helix are displaced from one groove to its adjacent neighbor. Since the spacing of the grooves varies according to the space of the teeth of the gear train, the turns will not reside in equilibrium in their new locations but will be located in contact with the sides of the grooves. Assume fifty-one turns of the helix are enclosed by arms 40, with the average pitch of twenty-five being less than the "ideal" turn-to-turn spacing by an amount $-\Delta x$ (i.e., reside on the right side of the grooves, assuming positive movement

to the left), while twenty-six are above this average amount (i.e., reside on the left side of the grooves) by Δx, this being a valid assumption since the average of teeth spacing on the lead screw is a constant from lathe to lathe.

The excess number of turns of helix of the left side of the grooves creates a net force along the axis of the assembly which tends to move the mandrel to the right relative to the wire feed assembly **10**, as viewed in FIGURE 3, uniformly affecting the pitch of the helix turns being simultaneously formed. The length of such movement is equal to the magnitude of the force vector **52**, which is proportional to the difference of the turns divided by the lesser amount of turns in one direction times the average turn-to-turn spacing of the turns. For the example advanced above

$$F \propto 26\text{–}25/25|\Delta x|$$

where F equals the magnitude of force vector **52** and $|\Delta x|$ is the absolute value of the spacing variant. However, note that F, force vector **52**, in the above equation is progressively diminishing towards zero during the operating cycle since the axial positions of the helix turns relative to grooves **47** approach the respective mid-points of the latter as more uniformly spaced helix turns are formed and confined.

Freedom for movement to compensate both the non-uniform movement of the winding carriage and the reaction of forces of the system is provided by the attachment of mandrel **9** to "free floating" chuck assembly **12** mounted to head stock **3**. Referring to FIGURES 2 and 5, chuck assembly **12** comprises a cylindrical housing **57** located coaxially of and slideable with a chuck shaft **58** attached at one end to collet **13** and having an end wall **59** to which is attached a conventional chuck **60** to secure mandrel **9**.

Axial movement of the housing **57** relative to the shaft **58** is provided by reducing the diameter of the latter below that of the housing and locating linear ball bearings **61** and **62** in contact with its inner wall. Rotational motion of the mandrel **9** is provided by transferring the movement of collet **13** directly to shaft **58**, housing **57**, and chuck **60**, the shaft and housing being integrated by the engagement of the outer peripheries of rollers **63** of shaft **58** with slot **64** of housing **57**. Rollers **63** are attached to the shaft on diametrically opposed locations by outwardly extending pins **65** and are rotatable in a plane at right angles relative to axis A—A of the assembly to facilitate axial movement of the housing relative to the shaft. Such movement is limited, however, by the length of the slot **64** within the housing of the chuck assembly.

For operation of the adapter assembly, the mandrel is initially located in a fixed relationship with respect to the lathe bed, after which the mandrel is freed for travel along a path parallel with the axis of symmetry of the mandrel, as explained hereinafter. Such action is provided in the chuck assembly **12** by eccentric chuck wheel **66**, rotatable with respect with and mounted to housing **57**, as by pin **56**, having an inner eccentric surface **67** located adjacent an opening **53** in housing **57**. As chuck wheel **66** is rotated with respect to housing **57**, spring-loaded axial detent pin **68** is inserted through the housing into and from centrally disposed groove **70** in chuck shaft **58**, thereby locking or unlocking the axial travel of the mandrel.

The operation of the coil winding apparatus, in particular the manner of operation of the adapter assembly of the invention, will be better understood by reference to FIGURES 5, 6, and 7.

After wire feed assembly **10** is secured to the carriage **5**, wire **28** is threaded through wire tensioning clamp rollers **29** (FIGURE 2) and thereafter through an opening **54** in the mandrel **9** where it is bonded as with a good adhesive

such as glue, cement, or the like. Mandrel **9** in turn is mounted to "free floating" chuck assembly **12** in a plane such that it extends adjacent clamping mechanism **14** of wire feed assembly **10** as explained above.

The desired pitch or turns or distance between turns, determined by the angular velocity of the mandrel and by the pitch of the lead screw, is set by proper engagement of change gear selector and key located on the head stock face. The lathe is then turned on, and rotation of the lathe collet **13**, mandrel **9**, and lead screw **6** (FIGURE 1) occurs. Translational movement is provided carriage **5** and wire feed assembly **10** along a path adjacent mandrel **9**, i.e, from left to right as viewed in FIGURE 5 by engagement of carriage **5** with lead screw **6**. Such movement, coupled with the attachment of wire **28** to mandrel **9**, causes a short length of helix **28***a* to be laid down on the mandrel. The spacing of the turns of the helix thus formed is proportional to the spacing of the gear teeth of the lead screw, the mandrel being fixed relative to the lathe bed by the engagement of axial detent pin **68** with groove **70** in chuck shaft **58** of "floating" chuck assembly **12** (see FIGURE 6).

It is to be noted that during this time period the helix clamping mechanism **14** comprising arms **40** and bearings **56** does not engage the turns of the helix. Shortly thereafter, however, arms **40** and more particularly bearings **46** are brought into engagement with the helix by rotating actuating lever **44** from left to right as shown in FIGURE 2 causing cables in contact with the arms to become taut.

Eccentric wheel **66** is then rotated relative to the mandrel **9** to disengage axial detent pin **68** from groove **70** of chuck shaft **58**, freeing the mandrel and chuck for axial travel along the axis A—A of the apparatus as shown best in FIGURE 7, such travel being controlled by movement of the carriage and wire feed assembly **10** since the mandrel, chuck, and carriage are integrated by the engagement of the turns of the helix with the grooves **47** (FIGURE 4) formed within the bearing inserts as explained above.

When the carriage has traversed the length of the mandrel, the lathe is stopped, the final turn of the coil is secured to the mandrel with an adhesive to prevent unwinding. The wire is then cut, and the mandrel with the coil thereon is removed from the chuck for further processing of the coil. It has been found that coils may be wound on the described apparatus from wire having diameters of the order of .006 inch, with spacing between turns of as little as .012 inch, to a very high degree of accuracy, i.e., having variations of less than $\pm$.0002 inch between turns.

Changes, modifications and improvements in the invention may occur to those skilled in the art without departing from the spirit of the invention as defined by the following claims.

We claim:

1. Helix winding apparatus comprising
   - a mandrel having a longitudinal axis, means for supporting said mandrel for rotation about said axis and for relatively free axial movement,
   - means for rotating said mandrel,
   - a carriage supported adjacent to said mandrel,
   - means for moving the carriage longitudinally of the mandrel,
   - a supply of wire on said carriage arranged to guide wire tightly on said mandrel to form the helix, and
   - a clamp on said carriage having resilient jaws engageable with the helix on said mandrel, whereby variations in the rate of longitudinal movement of said carriage produce a corresponding shifting of the helix and mandrel along said longitudinal axis.

2. Apparatus for winding wire on a mandrel to form a helix with a predetermined spacing between turns comprising, in combination,
   - a lathe including a lead screw, a chuck, and means for

driving said lead screw and chuck in rotation about respective axes; said chuck comprising a shaft and a housing slideably mounted on said shaft, said housing being connected to said mandrel; and

a wire supply assembly connected to said lead screw supported for longitudinal movement along a path adjacent the mandrel in response to rotation of said lead screw including means for guiding wire onto the mandrel to form a helix and a resilient body engageable with turns of a portion of said helix for attachment of said mandrel to said guide assembly, non-uniform movement of said guide assembly thereby producing a corresponding longitudinal movement of the helix and mandrel.

3. Apparatus for winding wire on a mandrel to form a coil or helix with a predetermined spacing between turns comprising, in combination,

a lathe including a lead screw, a chuck, and means for driving said lead screw and chuck in rotation about parallel axes, said chuck comprising a shaft and a housing slideably mounted on said shaft, said housing being connected to said mandrel, and

a wire supply carriage connected to said lead screw arranged for movement along a path adjacent and parallel to the rotational axis of the mandrel in response to rotation of said lead screw and including means for guiding wire onto said mandrel to form a helix, and a clamping mechanism including resilient bearings connected to said supply carriage and diametrically located on opposite sides of the mandrel axis for engagement with turns of a portion of said helix for attachment of said mandrel to said carriage, non-uniform movement of said carriage thereby producing a corresponding movement of the helix and mandrel along a path parallel with said rotational axis of the lead screw.

4. Apparatus for winding wire on a mandrel to form a helix with a predetermined spacing between turns comprising, in combination,

a lathe including a lead screw, a chuck, and means for driving said lead screw and chuck in rotation about parallel axes, said chuck comprising a shaft and a housing slideably mounted on said shaft, said housing being connected to said mandrel and means arranged for releaseably securing said housing to said shaft; and

a wire supply assembly connected to said lead screw supported for longitudinal movement along a path adjacent and parallel to the axis of the mandrel in response to rotation of said lead screw, including means for guiding wire onto said mandrel to form a helix and a resilient body located about said mandrel having an initial flat surface engageable with turns of a portion of said helix for attachment of said mandrel to said feed assembly, non-uniform movement of said feed assembly thereby driving said mandrel along a path parallel with said rotational axis of the lead screw.

5. Apparatus for winding wire comprising, in combination,

a mandrel,

a rotatable chuck assembly having a shaft and a housing slideably mounted on said shaft, said housing connected to said mandrel,

a lead screw rotatable with said chuck assembly,

means for driving said lead screw and said chuck in rotation about co-extensive axes,

a first carriage mounted on said lead screw and arranged for movement therealong in response to rotation of said screw,

a second carriage mounted to said first carriage, said second carriage including means for guiding wire onto said mandrel from a direction substantially normal to said mandrel to form a helix, and

a clamping mechanism comprising resilient bearings diametrically located on opposite sides of said mandrel engageable with turns of a portion of said helix for attachment of said mandrel to said second carriage, non-uniform movement of said first carriage thereby producing corresponding movement of said mandrel.

6. Apparatus for winding wire comprising, in combination,

a mandrel having an axis,

a rotatable chuck assembly having a shaft and a housing slideably mounted on said shaft, said housing connected to said mandrel,

a lead screw rotatable with said chuck assembly,

means for driving said lead screw and said chuck assembly in rotation about parallel axes,

a first carriage mounted on said lead screw and arranged for longitudinal movement therealong in response to rotation of said screw,

a second carriage mounted to said first carriage, said second carriage including means for guiding wire onto said mandrel from a direction substantially normal to said mandrel, to form a helix, and

a clamping mechanism attached to said second carriage comprising resilient bearings diametrically located on opposite sides of said mandrel, said bearings initially having flat, planar wearable surfaces engageable with a portion of said helix thereby forming a series of grooves thereon through which said helix serpentines for attachment of said mandrel to said second carriage, non-uniform movement of said first carriage thereby producing a corresponding movement of the helix and mandrel along said mandrel axis.

7. Apparatus for winding wire on a mandrel comprising, in combination,

a chuck assembly having a shaft and a housing slideably mounted on said shaft, said housing being connected to said mandrel, and means arranged for releasably securing said shaft to said housing including an annular member having an eccentric inner surface;

a lead screw rotatable with said chuck assembly;

means for driving said lead screw and said chuck assembly in rotation about parallel axes;

a first carriage mounted on said lead screw and arranged for longitudinal movement therealong in response to rotation of said screw;

a second carriage mounted to said first carriage, said second carriage including means for guiding wire onto said mandrel to form a helix and a pair of bearings diametrically located on opposite sides of said mandrel axis initially having flat, planar wearable surfaces engageable with a portion of said helix thereby forming a series of grooves for attachment of said mandrel to said second carriage;

pulleys attached to said bearings having peripheral grooves arranged for free rotation about axes parallel to the axis of said lead screw;

first and second cables passing over said peripheral grooves and respectively conencted to said bearings; and

means connected to said cables for maintaining said cables in tension.

8. Helix winding apparatus comprising

a base,

a mandrel having an axis,

a chuck supporting said mandrel for rotation about said axis,

means for supporting said chuck on said base for movement along the axis of said mandrel,

a carriage supported on said base adjacent to said mandrel, and

means for driving said carriage parallel to and for rotating said mandrel about said axis,

said carriage including means for guiding wire onto the mandrel to form a helix and a resilient body means engageable with a portion of the helix for attachment of said mandrel to said carriage whereby variations in the rate of axial movement of said carriage produce a corresponding shifting of the helix and mandrel along said axis.

9. Apparatus for winding wire on a mandrel having an axis comprising, in combination,

a base,

a chuck assembly rotatably supported on said base and having a shaft and a housing slidably mounted on said shaft, said housing being connected to said mandrel for supporting the latter in rotational and axial movement,

a lead screw rotatably supported on said base for rotation in synchronism with said chuck assembly and said mandrel,

means for rotating said lead screw and said chuck, and

a carriage mounted on said lead screw and arranged for movement therealong in response to rotation of said screw, said carriage including means for guiding wire onto said mandrel to form a helix, and a body engageable with turns of a portion of said

helix for attachment of said mandrel to said carriage.

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DONALD W. PARKER, *Primary Examiner.*

RUSSELL C. MADER, MERVIN STEIN, *Examiners.*