Jan. 10, 1928. 1,655,997

W. C. FURNAS

WINDING MACHINE AND PROCESS OF BENDING STRIP MATERIAL

Filed Jan. 14. 1924 2 Sheets-Sheet 1

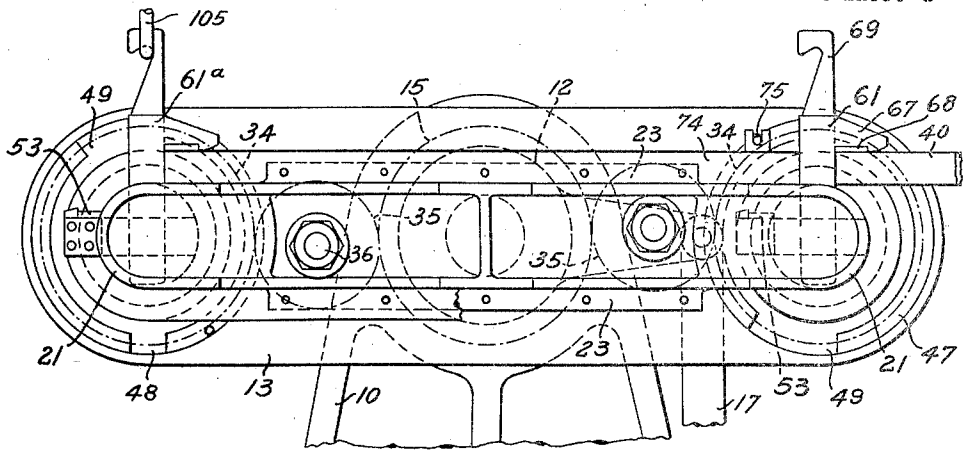


Fig. 1

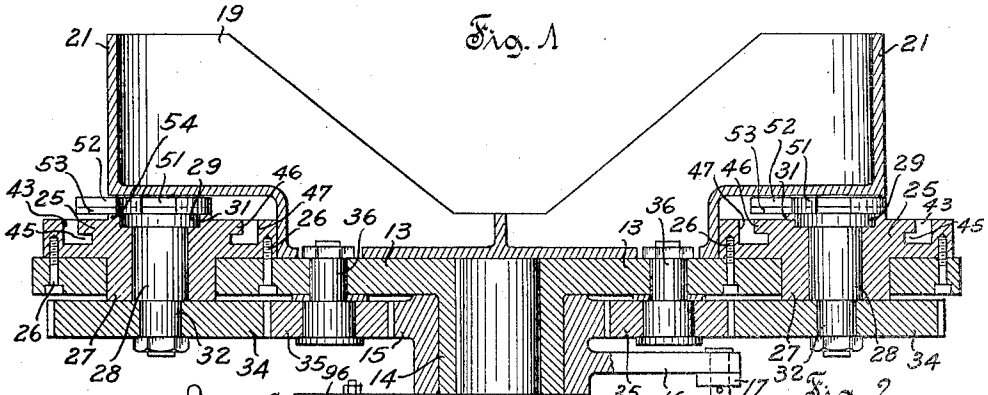


Fig. 2

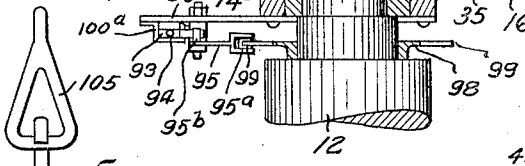


Fig. 3

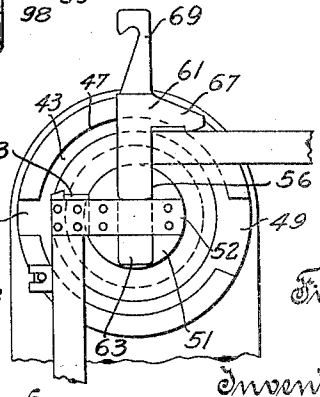


Fig. 4

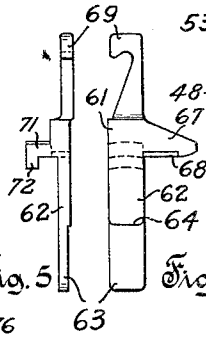


Fig. 5

Fig. 6

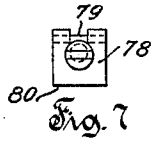


Fig. 7

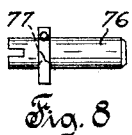


Fig. 8

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WINDING MACHINE AND PROCESS OF BENDING STRIP MATERIAL

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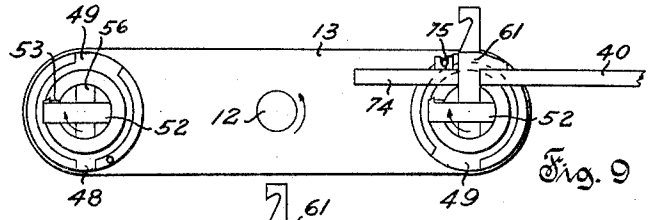


Fig. 9

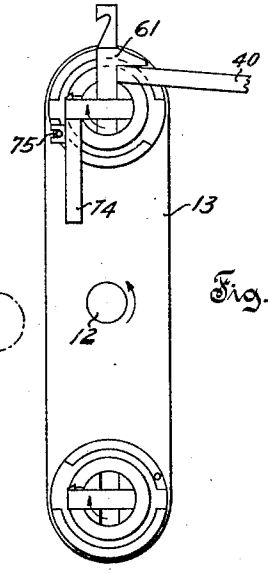


Fig. 10

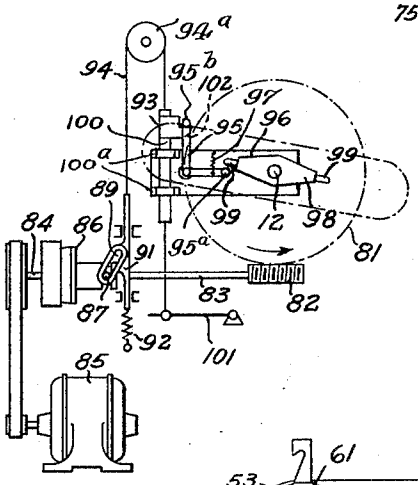


Fig. 13

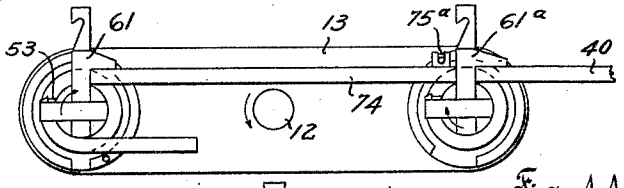


Fig. 11

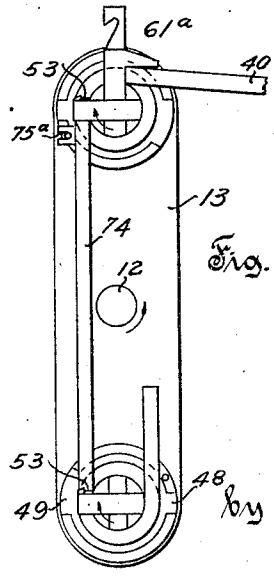


Fig. 12

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UNITED STATES PATENT OFFICE.

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WINDING MACHINE AND PROCESS OF BENDING STRIP MATERIAL.

Application filed January 14, 1924. Serial No. 685,948.

This invention relates in general to the art of metal bending, and has more particular relation to bending strip material edgewise, as for the purpose of forming coils such as are of special utility as electromagnet coils for dynamo-electric machines and otherwise.

In bending strip material, especially material of large size, in an edgewise manner, there is a crowding over or enlargement of the material adjacent the inner edge of the bend and a tendency toward stretching or reduction of the thickness or cross-section of the material adjacent the outer edge of the bend. Where it is necessary or desirable to preserve substantially uniform thickness of the material throughout, as is especially desirable in the case of electromagnet coils formed from strip material bent or wound edgewise, this enlargement at the inner edge of the bend is a decided disadvantage, since it requires a further operation to reduce or reform the enlarged wedge-shaped section usually a grinding, cutting or swaging operation independent of the bending operation.

The crowding or enlarging of the cross-section at the inner edge of the bent strip material is especially objectionable in electromagnet coils, especially field coils for dynamo-electric machines, for, unless removed, the over-all size of such a coil is unduly increased. It has been commercial practice in the past, in the formation of coils of large size, to first bend the material to form the complete coil and then separate the turns of the coil and to grind or swage the enlarged portions at the inner edge of the bend of the individual turns successively, the individual turns being later pressed back into the desired coil formation of as small axial dimension as possible. These operations of reducing to desired size the material at the inner edge of the bend and the subsequent reforming of the coil are performed at great expense and delay.

The present invention is related to and, as to features concerned with the bending and removal of excess thickness from a bent portion of the material, constitutes an improvement upon the invention of the application of G. F. Johnston, Serial No. 685,946, filed January 14, 1924.

Features of the present invention contemplate the production of objects formed from bent strip material, especially objects formed from material of relatively great size as to thickness or width, and wherein the excess thickness of material at the inner edge of bends is removed during the bending operation, this operation of removing the excess material being directly associated with the operation of bending the material, and the operations being successive and continuous. A further feature of the invention contemplates and includes an apparatus automatically operative to form bends, especially a series of bends as features of a coil, and to remove excess material from the inner edge of the bends, the combined operations of bending and reducing the bent or coiled material to the desired final shape being performed at a considerably reduced cost and in considerably less time than is required for the several operations of bending and trimming the material at the bend, as practiced in the past.

An object of the present invention is to provide an improved method and apparatus especially adapted for producing bent strip material wherein excess thickness formed at the inner side of the bend is reduced through an operation directly associated with the bending operation.

It is a further object of the present invention to provide an improved method and apparatus especially adapted for the production of objects formed from strip material bent or coiled edgewise and in accordance with which the material may be bent and all of the excess thickness at the inner side of the bend may be reduced during the bending operation or a continuation thereof.

It is a further object of this invention to provide an improved apparatus for forming edgewise wound coils, wherein the material to be wound is fed to a rotatable form, and bending and cutting devices are operable simultaneously with and relative to the form for the purpose of bending the material and removing therefrom excess thickness at the inner edge of the bent portions.

These and other objects and advantages are attained by the present invention, various novel features of which will be apparent from the description and drawings herein,

disclosing an embodiment of the invention, and will be more particularly pointed out in the claims.

In the accompanying drawings:

Fig. 1 is a front elevation of a coil winding apparatus embodying features of the present invention;

Fig. 2 is a horizontal section through the axis of the machine as shown in Fig. 1;

Fig. 3 is an end elevation of the apparatus of Fig. 1;

Fig. 4 is a front elevation of a detail of the apparatus of Fig. 1, parts being removed, with the machine in a position 90 degrees removed from the position of Fig. 1;

Figs. 5 and 6 are front and side elevations, respectively, of a bending tool forming a feature of the apparatus of Fig. 1;

Figs. 7 and 8 are front and side elevations, respectively, of a clamping device forming a further detail of the apparatus of Fig. 1;

Figs. 9, 10, 11, and 12 are diagrammatic views showing the relative positions of co-operative parts of the apparatus of Fig. 1, during the normal operation of such apparatus; and

Fig. 13 is a diagrammatic view showing a detail of the control of the apparatus of Fig. 1.

In accordance with the disclosure of the drawings, a frame or support 10 is provided with suitable bearings for a shaft 12 which has keyed, or otherwise secured, to an end thereof a rotatable carrier or support 13, a hub portion 14 of the latter bearing upon the shaft and constituting the means of support and attachment of the carrier to the shaft. The hub portion 14 is rotatable within a stationary gear 15, the latter being held against movement by means of an arm 16 secured to a hub portion of the gear and a rod 17 attached to the outer end of the arm and to a fixed point of support, such as the frame 10. A form 19 in the shape of an elongated spool about which strip material is to be bent or wound to form turns of a coil of the type which may be used for an electromagnet, such as the field coil of a dynamo-electric machine, is provided with semi-circular ends 21 about which the strip material is to be bent, and side portions having flanges 23 at their inner edges, these flanges constituting means for attaching the form or supporting spool to the outer face of the rotatable carrier 13.

A plurality of disk-shaped elements or forming blocks 25 are disposed at the ends of the arms of the rotatable carrier 13, with their axes in alinement with the axes of the semi-circular ends 21 of the forming spool. Each of these elements 25 is secured in position on the carrier by means of bolts 26, and each has a rearwardly extending hub portion 27 which fits within an aperture in the rotatable carrier 13. A shaft or pintle 28 is mounted in the axial bore of each hub portion 27 in the element 25, the shaft being provided with a head 29 occupying a central countersunk recess 31 in the outer face of the element 25. The front end of each shaft 28 is provided with an extension 32 upon which is mounted a spur gear 34. Idler gears 35 are mounted upon shafts 36 which are passed through and mounted in operative position on the rotatable carrier 13. The idler gears 35 constitute driving connections between the stationary gear 15 and the spur gears 34 coaxial with the semi-circular ends 21 of the supporting spool 19. Through the arrangement of gears described, a planetary gear drive is provided of such design that each spur gear 34 and its shaft is caused to make one revolution about their axis during a single revolution of the shaft 12 and the rotatable carrier 13, the rotation of the carrier and the spool 19 carried thereby being anti-clockwise, as viewed in Fig. 1, and the rotation of the shafts 28, which are driven through the rotation of the carrier, being clockwise (all as indicated in Figs. 9, 10, 11 and 12).

A section of strip material to be bent or wound edgewise is indicated at 40, it being intended that this material shall be bent or wound in such a manner as to form the several turns of a coil of the shape of the form 19 and such as may be used for an electromagnet for the field element of a dynamo-electric machine, or otherwise. As indicated in Fig. 1, this strip material 40 is bent around the semi-circular end 21 at the left of the forming spool, it being intended that the succeeding operation will bend such strip material around the semi-circular end 21 at the right of the forming spool.

The front face of each of the disk-shaped elements or forming blocks 25, is provided with a substantially circular recess 43 having an inwardly cut portion 45, the arrangement providing an annular shoulder 46 and an outer boundary wall 47, the latter being recessed at diametrically opposite points 48 and 49, as indicated, and the recess 49 being extended at the leading side, considered with respect to the direction of rotation of the element 25. A disk-shaped head 51 at the outer end of each of the shafts 28 serves as a tool holder. Mounted in a recess in the outer face of the tool holder 51 is a holder 52 for a cutting tool 53, the line of the cutting edge of said tool being displaced from and substantially parallel to a radius through the axis of the shaft 28. The cutting edge of the tool 53 is displaced from the front face of the disk-shaped element 25 by means of an axial projection 54 on the latter element and with which the tool holder cooperates to maintain the desired space between the parts.

The tool holder is likewise provided with a

second rectangular recess 56, arranged at substantially right angles to the recess in which the holder for the cutting tool is mounted. A forming tool 61 having a body portion or shank 62 with a reduced extension 63 and a shoulder 64 is provided for ready insertion within and removal from the recess 56, the reduced extension 63 of the shank portion passing beneath the holder 52 for the cutting tool, with the shoulder 64 limiting the insertion of the shank into the recess. The forming tool 61 is provided with a lateral extension 67, in a recess in the lower face of which a hardened wearing plate 68 is mounted. The outer end of the shank portion 62 terminates in a hook-shaped portion 69. The plate 68 is maintained at such a distance from the center of rotation of the shaft 28 that it bears forcibly against the outer side of the strip material to be wound on the semi-circular end 21 of the forming spool 19; and it is through the forcible bearing of the wearing plate 68 against the edge of the strip material that the latter is bent during rotation of the forming tool about its axis. The shank portion 62 of the forming tool is also provided with a rear extension 71 having a projection 72 thereon. When the tool holder is in operative position, the extension 71 fits in the circular recess 43, with the projection 72 in the under-cut recess 45 and engaging against the shoulder 46 to prevent withdrawal of the forming tool in an axial direction. Likewise, the engagement of the projection 72 with the shoulder 46 limits the separation of the inner side of the shank portion from the outer face of the element 25, this distance corresponding to the width of the strip material being wound with allowance for increasing thickness during the bending operation. The forming tool 61 can readily be removed in a radial direction from the operative position shown in Figs. 1 and 4.

To appreciate the operation of the process and apparatus, one can assume that the initial bend of the strip material 40 has been made about the semi-circular end of the former at the left in Fig. 1, or that the strip material is otherwise held in position, and that the forming tool 61 has been inserted to operative position with respect to the shaft 28 and the portion of the form 19 at the right in Figs. 1 and 9.

74 indicates a portion of the strip material constituting a straight side of the turn of a coil being formed. In order to prevent distortion of this straight portion of the turn during the succeeding bending operation, a clamping device 75 is provided, the same including a shank portion 76 rotatable in and readily insertible in and removable from an aperture in the boundary wall 47 of the element 25 at a point to the rear of the recess 48 therein. This shank portion 76 is provided with an annular eccentrically disposed recess 77 near its outer end; and a clamping block 78 having a recess provided with a curved wall closely engageable with that of the recess 77, a pin 79 being provided to hold the clamping block in operative position in the recess. As will be apparent from the drawings, rotation of the shank or stem 76, as by applying a tool to the screw head thereof, will cause the lower straight clamping edge 80 of the clamping block to be reciprocated to and from forcible engagement with the edge of the straight portion 74 of the coil turn. When the clamping device is in operative position, as indicated, the straight sides of the coil are prevented from bulging or distorting outwardly.

With the clamp 75 in operative engaging position and the forming tool 61 inserted to operative position and held therein by the pin 65, as indicated in Figs. 1 and 9, the machine may be started. In operation, the carrier 13 rotates in an anti-clockwise direction, and through the planetary drive, the forming tool 61 and the cutting tool 53 are driven in a clockwise direction about their axis of rotation. The operating effect is that, as the carrier rotates from the position indicated in Fig. 9 to that indicated in Fig. 10, the forming tool 61 causes the strip material 40 to be bent around the semi-circular end 21 of the forming block or spool; and when the carrier is in a position indicated in Fig. 10, the strip material 40 has been bent through approximately 90 degrees. During the bending operation described, the thickness of the material has increased adjacent the inner edge thereof at the bent portion. Because of the forcible engagement between the shank of the bending tool and the enlarged bent material, and probably some holding action of the cutting tool 53 which follows the forming tool, substantially all of this increase in thickness appears at the outer face of the bent strip material. Just prior to the moment the parts have assumed the positions indicated in Fig. 10, the cutting tool 53 has started its cutting or shaving operation, its effect being to remove any previously formed excess thickness at the bent portion and thus cause the thickness at the bent portion to be uniform and of the desired dimension. The cutting action is one of shearing or shaving, as will be apparent from Fig. 3, wherein the action of the cutting tool 53 in removing the portion 40^a, corresponding to excess thickness, is indicated.

During rotation from the position indicated in Fig. 10 to that of Fig. 11 the bending action of the forming tool 61 continues, as does the action of the cutting tool 53. In the position in Fig. 11, the forming tool 61 has arrived at a position with respect to the disk 25 wherein the forming tool has completed the formation of the 180 degree

bend and, now being opposite the recess 49, may be removed from operative position so as to prevent distortion of the straight portion of the coil side, as might be produced by further rotation of the forming tool relative to the forming spool. Accordingly, the forming tool 61 is withdrawn in a radial direction through the recess 49. At this time, the recess 48 in the disk 25 at the right hand side of the forming spool 19, in Fig. 11, is in position wherein the forming tool 61 recently removed from the disk 25 at the left, or an additional forming tool 61^a, may be inserted vertically to operative position. Likewise, a clamping device 75^a may be inserted and secured in operative position, in a manner previously described, as indicated in Fig. 11. In view of the fact that the clamping device 75 which has traveled from the position at the right in Fig. 9 to a position underneath at the left in Fig. 11, is no longer necessary for preventing distortion of the straight sided portion 74 of the coil, this clamping device may be removed, as indicated in Fig. 11.

From the position indicated in Fig. 11, rotation of the carrier plate 13 and its appurtenant parts may be continued through the position of Fig. 12 and to a position corresponding to that of Fig. 9. During this operation of the carrier 13 through 180 degrees, a second semi-circular bend is produced in the strip material to form the opposite end of an oval-shaped turn of the coil being formed. During this operation, a portion of this semi-circular bend has had its excess thickness removed from the inner edge thereof, the remainder of this excess material being removed as the carrier is rotated further, from the position of Fig. 9 to that of Fig. 10.

Due to the fact that the bending and cutting tools rotate on their axis at the same angular speed as and in a direction opposite to the rotation of the carrier 13, the bending and cutting tools always extend in the same directions in space.

As each semi-circular bend is formed, the lower side of the bend, considering Fig. 11, may move outwardly or forwardly into proximity with the previously formed turns, as the carrier rotates to the position of Fig. 12 and slightly beyond, the cutting tool at this latter time having completed its cutting or shaving operation and occupying a position within the formed portion of the coil, as may be seen at the right in Figs. 9 and 11, and hence not preventing this forward movement of the coil side or the formed coil end. Thus, it will be apparent that as the portions of the coil are completed they are free to move automatically or to be moved forwardly from the disk 25 so as to permit the formation of a succeeding bend or turn about the forming spool.

In order to insure a sufficient interval of time to provide for the removal of the forming tool 61 from one end of the carrier subsequent to the completion of a semi-circular bend, and the insertion of this tool, or the insertion of another tool, at the opposite end of the forming spool, it is desirable to provide for the automatic stopping of the apparatus when the bends are completed, at which time the recesses 49 and 48 come into position to permit removal of one forming tool and the insertion of another forming tool.

As indicated in the drawings, Fig. 13, a worm gear 81 operated by a worm 82 may serve as the operating drive for the shaft 12. The shaft 83 of the worm 82 is driven from a shaft 84 operated by a motor 85, directly or through a belt drive, as indicated, a clutch 86 being provided between the shafts 82 and 83 the movable part of the clutch being provided with a pin 87 operating in a cam slot 89 of a clutch-operating element 91 having a guided reciprocating movement in a direction perpendicular to the axis of the shaft 83, the operating element 91 being normally biased by a spring 92 to a position wherein the clutch is released, The clutch parts are held engaged to provide an operating drive for the shaft 12, by reason of the fact that the operating element 91 is held in the position shown by a catch 93 which is flexibly connected to the clutch-operating element 91 through a flexible wire or the like 94 passing over a sheave 94^a, the catch 93 being held by a latch 95, shown in Figs. 2 and 13 in the form of a bell-crank lever and preferably provided with a pin or roller 95^b at that end which engages the catch 93. This latch 95 is pivoted on a bracket carried by a stationary arm 96 carried by the hub of the fixed gear 15, a spring 97 serving to bias the lever to latching position relative to the catch 93. An arm 98 is mounted on the shaft 12 for rotation therewith, extending in opposite directions from the shaft, and is provided with operating portions 99 at diametrically opposite points and in position to engage with and trip the latch 95, preferably through engagement with the pin or roller 95^a on the end of the latch, as the parts of the bending apparatus reach or pass beyond the position indicated in Fig. 13, the position of the parts in this figure being that assumed just prior to reaching the positions of Figs. 9 and 11. Releasing of the latch 95 by the operating portion 99 of the arm 98 permits the operating spring 92 to actuate the operating element 91, thus releasing the clutch and causing the rotatable carrier 13 and its appurtenant parts to stop immediately due to its own load or, if necessary or desired, the additional load of an applied brake. The catch 93 is preferably mounted on a reciprocating rod 100 which is constrained to the desired straight line movement by suitable

guides 100ª therefor mounted on the stationary arm 96.

The apparatus may be started again by applying pressure to a treadle 101, causing the catch 93 to be drawn down and the clutch 86 to be engaged, a cam surface 102 on the under side thereof riding over the end of the bell crank latch 95 until it is free thereof, the end of the latch then falling across the upper side of the catch 93 and preventing upward movement thereof and consequent release of the clutch and the driving connection to the carrier 13.

In order to insure that no damage may be done to the coil being formed, even though the operator fails to remove the forming tool 61 as the latter reaches the position of Fig. 11, an eye 105 is suspended in position wherein its cross bar will be engaged by the hook portion 69 of the forming tool as the tool holder tends to rotate beyond the position of Fig. 11, the forming tool being suspended on the eye and freeing and releasing itself from the element 25 as the latter continues its rotation, the enlargement of the recess 49 facilitating the removal of the bending tool.

In the operation of the apparatus, it is preferable that sections of strip material be fed from spools and joined together mechanically and electrically before being supplied to the bending apparatus, so that the operation of the rotatable carrier 13, with its forming spool and bending and cutting tools, may proceed until the required number of turns are formed to complete the total number of coils required. As the required number of turns per coil are formed and moved forward on the forming spool, the wound material may be cut at the proper point to permit removal of a completely formed coil of the desired number of turns.

While the invention has been described herein in connection with the formation of turns or coils of generally oval-shape with semi-circular bends, it will be apparent that features of present invention may be utilized in the formation of coils of any other shape, such as generally circular, triangular, rectangular, with 360, 120 and 90 degrees connecting bends, respectively, such coils being formed expeditiously when the bending tools are given the required operation as described and suggested herein.

It will be apparent that, in accordance with the process and apparatus of the present invention all excess thickness formed during the bending or winding of strip material may be removed during the operation of bending the material, and the final product may be a turn or a series of turns forming a coil wherein the strip material is of substantially the same thickness throughout.

It should be understood that the invention claimed is not limited to the exact details of construction and operation shown and described herein, for obvious modifications will occur to a person skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. In apparatus for bending strip material, the combination of a form, and means for accomplishing a combined bending and thickness-reducing operation on said material, said means and said form being relatively movable, and said means being operative during a continuous increment of relative movement to form the desired bend about said form while permitting increase in thickness of the strip material at its inner edge during actual bending of such material and to reduce the excess thickness of said material at all portions thereof produced during such bending.

2. In apparatus for bending strip material, the combination of a form, and an element provided with a bending device and a thickness-reducing tool, said form and said element being relatively movable, said element being operative during a continuous increment of said relative movement to cause said bending device to bend said material about said form and to cause said thickness-reducing tool to remove excess thickness formed during the bending thereof from all parts thereof adjacent the bent portion.

3. In apparatus for bending strip material about a form, means for producing relative rotation between the form and the strip material to cause the latter to be bent to the desired shape while permitting increase in thickness of the strip material at its inner edge during actual bending of such material, and means operable during said bending operation and during a continuous increment of said relative rotation for reducing excess thickness of all thickened parts adjacent the bent portion of said material.

4. In apparatus for bending strip material about a form, means for producing relative rotation between the form and the strip material to cause the latter to be bent to the desired shape while permitting increase in thickness of the strip material at its inner edge during actual bending of such material, and means rotatable during said bending operation and during a continuous increment of said rotation for reducing all of the excess thickness adjacent the bent portion of said material.

5. In apparatus for bending strip material, a rotatable carrier, a form mounted on said carrier and about which strip material may be bent, and a bending element cooperative with said strip material and operative to bend said material about said form during rotation of said carrier, and means operative during the rotation of said carrier

for removing excess material from the bent portion of said strip material.

6. In apparatus for bending strip material, a rotatable carrier, a form mounted on said carrier and about which strip material may be bent, a bending element carried by and rotatable relative to said carrier and cooperative with said strip material to bend the latter about said form during rotation of the carrier, and means operative during the rotation of said carrier for removing excess material from the bent portion of said strip material.

7. In apparatus for bending strip material, a rotatable carrier, a form mounted on said carrier and about which strip material may be bent, a bending element cooperative with said strip material and operative to bend said material about said form during rotation of said carrier, and means carried by and rotatable relative to said carrier during the operation of the latter for removing excess thickness from the bent portion of said material.

8. In apparatus for bending strip material, a rotatable carrier, a form mounted on said carrier and about which strip material may be bent, a bending element carried by and rotatable relative to said carrier and cooperative with said strip material to bend the latter about said form during rotation of the carrier, and means carried by and rotatable relative to said carrier during the operation of the latter for removing excess thickness from the bent portion of said material.

9. In apparatus for bending strip material into a series of separate bent portions, a form, a bending element cooperative with said material and adapted to bend the latter about said form, and means inherently operative to remove from each bent portion the excess thickness thereof prior to the formation of a succeeding bent portion of said material.

10. In apparatus for bending strip material into a series of separate bent portions, a carrier, a form mounted on said carrier, a bending element mounted on said form and cooperative with said material to bend the latter about said form, and means inherently operative to remove from each bent portion of the material the excess thickness thereof prior to the formation of a succeeding bent portion.

11. In apparatus for bending strip material into a series of separate bent portions, a carrier, a form mounted on said carrier, a bending element mounted on said form and cooperative with said material to bend the latter about said form, and means inherently operative to remove from each bent portion of the material the excess thickness thereof prior to the formation of a succeeding bent portion, said means comprising a cutting tool rotatably mounted on said carrier.

12. In a machine for winding strip material edgewise, a rotatable form about which material may be bent to form complete turns, a bending element cooperative with the material and rotatable about said form during rotation of the latter to cause the material to bent to the desired shape, and a tool rotatable relative to said form and adapted to remove excess thickness from the inner edge of the bent portion.

13. In a machine for winding strip material edgewise, a rotatable form about which material may be bent to form complete turns, a bending element cooperative with the material and rotatable about said form to cause the material to be bent to the desired shape, and a tool rotatable in a direction opposite to that of said form and adapted to remove excess thickness at the inner edge of the bent portions.

14. In a machine for winding strip material edgewise, a form about which the material may be bent to form complete turns, a bending element cooperative with the material and rotatable about said form to cause bending of said material to the desired shape, and a cutting tool rotatable relative to said form and adapted to remove excess thickness formed at the inner edge of the bent portion of the material through a movement which is partly in continuation of the movement of said bending element, the cutting edge of said tool being at an angle to a radius through said cutting edge and the center of rotation of said tool.

15. In a machine for winding strip material edgewise, a rotatable form about which material may be bent to form complete turns, a bending element cooperative with the material and rotatable about said form to cause the material to be bent to the desired shape, and a cutting tool rotatable in a direction opposite to that of said form and adapted to remove excess thickness at the inner edge of the bent portion, the cutting edge of said tool being rearwardly inclined.

16. In apparatus for winding strip material edgewise, a rotatable non-circular form having spaced portions of arcuate contour, a tool for bending said material about said form during rotation of the latter, a thickness-reducing tool rotatable about an arcuate portion of said form, and a planetary gear drive connection between said form and said thickness-reducing tool to cause rotation of the latter relative to said form, said thickness-reducing tool being adapted to remove excess thickness at the inner edge of the portion of the material bent about said arcuate portion.

17. In an apparatus for winding strip material edgewise, a rotatable non-circular

form having spaced portions of substantially circular contour, a bending tool cooperative with said material to bend the latter about said form, a cutting tool rotatable about the axis of a circular portion of said form, and a planetary gear drive connection between said form and said cutting and bending tools to cause rotation of the latter relative to said form, said cutting tool being adapted to remove excess thickness at the inner edge of a portion of the material bent about said circular portion of said form.

18. In a power-driven machine for bending strip material edgewise, a rotatable carrier, a non-circular form carried thereby and having a plurality of arcuate portions connected by substantially straight portions, a bending tool having a portion cooperative with the edge of the material to be bent, a cutting tool cooperative with the bent portion of said material and adapted to remove excess thickness thereof during rotation of said carrier, and a driving connection between said rotatable form and said bending and cutting tools.

19. In a machine for bending strip material, a rotatable form of the desired shape of bend, a bending tool cooperative with said material and adapted to bend the material about said form, a cutting tool adapted to remove excess thickness adjacent the inner edge of a bent portion of said material, means for producing relative rotation between said bending and cutting tools and said form, and means for insuring retention of said bending tool in operative position during the bending operation and permitting removal of said tool only on completion of said bending operation.

20. An edgewise winding machine, comprising, a rotatable carrier, a form mounted on said carrier and about which strip material may be bent to form an edgewise wound coil, and a bending element cooperative with said strip material and operative to bend said material about said form during rotation of said carrier.

21. In apparatus for forming coils of strip material, a rotatable support, a form mounted on said support and rotatable relative to the strip material fed thereto, and a bending tool carried by said support and rotatable relative thereto and cooperative with said material during rotation of said form to bend the material about said form.

22. In apparatus for forming coils of strip material, a rotatable support, a form comprising straight portions connected by semi-circular ends mounted on said support and rotatable relative to the strip material fed thereto, and a bending tool carried by said support and rotatable relative thereto in an angularly opposite direction, said bending tool being cooperative with said material during rotation of said form to bend the material about a semi-circular portion of said form.

23. In apparatus for forming coils of strip material, a rotatable support, a form mounted on said support and rotatable relative to the strip material fed thereto, and a bending tool carried by said support and rotatable relative thereto and cooperative with said material during rotation of said form to bend the material about said form, the relative rotation of said bending tool being in a direction opposite to that of said support and at substantially the same speed as the latter.

24. The combination in a winding machine, of a rotatable non-circular form of definite shape, a bending tool, and means whereby said bending tool is constrained to move relative to the rotatable form so that the material being bent is always in substantially the same position relative to the portion of the form upon which it is being laid.

25. In a power-driven machine for winding strip material edgewise, a rotatable carrier, a form mounted on and rotatable with said carrier and having a curved portion, and a rotatably mounted, axially adjustable bending tool having its axis of rotation substantially coincident with the center of curvature of the curved portion of said form and cooperative with said strip material to bend the same about said curved portion during rotation of said carrier.

26. In a machine for winding metallic strip material edgewise in the form of a coil, a rotatable carrier, a form mounted thereon and having a peripheral contour which is composed of straight sections and curved sections, a removable device constituting a combined guide for preventing buckling of said strip material and for bending said material about curved portions of said form, and means for rotating said device in a direction opposite to that of said form to cause the bending of the strip material about a curved portion of said form while permitting rendering said device inoperative during the laying of straight portions of a wound coil.

27. In a machine for bending strip material, a rotatable form of the desired shape of bend, a bending tool cooperative with said material and adapted to bend the material about said form, means for producing relative rotation between said bending tool and said form, and means for insuring retention of said bending tool in operative position during the bending operation while permitting removal of said tool on completion of said bending operation.

28. In a power-driven machine for winding strip material edgewise, a rotatable carrier, a form carried thereby and having a curved portion, a bending tool cooperative

with said strip material to bend said material about the curved portion of said form and mounted for rotation and axial adjustment with its axis of rotation substantially concident with the center of curvature of said curved portion of the form, and a power connection between said carrier and said bending tool to cause the latter to be rotated at an angular speed equal to that of said carrier and in a direction opposite to that of said carrier.

29. In a machine for bending strip material edgewise, a rotatable carrier, a form carried thereby and having a portion of arcuate contour, a bending tool cooperative with the edge of the material to be bent, said bending tool being rotatable relatively to said form to cause said material to be bent about said arcuate portion of the form, a power connection between said carrier and said bending tool to cause rotation of the latter, and means for causing stoppage of said carrier on completion of a bend.

30. In a machine for bending strip material edgewise, a rotatable carrier, a non-circular form carried thereby and having a plurality of bent portions connected by substantially straight portions, a bending tool cooperative with the edge of the material to be bent, said bending tool being rotatable relatively to said form to cause said material to be bent about said form, a power connection between said carrier and said bending tool to cause rotation of the latter, and means for causing removal of said bending tool from operative position upon the completion of a bend in said material.

31. In a power-driven machine for bending strip material edgewise, a rotatable carrier, a non-circular form carried thereby and having a plurality of bent portions connected by substantially straight portions, a bending tool cooperative with the edge of the material to be bent and with a side thereof to hold the latter against an abutment, said bending tool being rotatable relatively to said form to cause said material to be bent about the form, a power connection from said carrier to said bending tool to cause rotation of the latter, means for insuring retention of said bending tool in operative position until the completion of a bend in said material while permitting removal of said tool upon completion of said bend, and means for causing removal of said bending tool from operative position upon the completion of said bend.

32. In a power-driven machine for winding strip material edgewise, a rotatable carrier, a form having a portion of circular contour, a bending tool cooperative with said strip material to bend said material about the circular portion of said form, a thickness-reducing tool adapted to remove excess thickness from said material bent about said circular portion of the form, said bending and thickness-reducing tools being mounted for rotation about the axis of said circular portion of the form, and means for rotating said tools at an angular speed equal to that of said carrier and in a direction opposite to that of said carrier.

33. In apparatus for producing coils formed of strip material, a rotatable form having portions of curved contour, and means associated with said form and rotatable relatively thereto and during rotation thereof and adapted to reduce excess thickness of the overlying curved portions of the coil successively.

34. In a machine for winding strip material, a rotatable form, means for feeding material to and bending the same about said form, and means continuously operative relative to and during the rotation of said form and the operation of bending said material and adapted to remove excess thickness formed at the inner edge of the bent portion of the material.

35. The combination of means for bending and winding strip material edgewise at definite intervals whereby a coil of noncircular shape is produced, and means operating concurrently with the bending operation to maintain uniformity of cross section throughout the material of the shaped coil, said latter means including a cutting tool adapted to shave all of the excess thickness from the inner edge of a bent portion of the shaped coil through an operation which is continuous with the bending operation.

36. The combination of a non-circular coil form, a bending element movable peripherally about a portion of said form and adapted to dispose strip material in desired bent shape about said portion of said form, means for temporarily holding a portion of said strip material in place, means for removing excess thickness from a bent portion of said material in advance of a succeeding traverse of said bending element, and means for supporting formed and reduced turns of said coil.

37. An improvement in the art of forming bent material subject to increase in thickness during the bending operation, which comprises bending said material and removing by an operation continuous with the bending operation all of the excess thickness produced adjacent the bend during the bending operation.

38. An improvement in the art of producing bent strip material subject to increase in thickness during the bending operation, which comprises bending said material while one face thereof is forcibly held by a traveling element against an abutment, and removing through an operation which is continuous with the bending operation all of the excess thickness of the material pro-

duced at the opposite face thereof during the bending operation.

39. An improvement in the art of producing coils of strip material subject to increase in thickness during the bending operation, which comprises bending said material about a form to complete a turn and removing from said bent material excess thickness at all thickened portions thereof through an operation which is continuous with the bending operation.

40. An improvement in the art of producing coils having a plurality of turns of strip material bent edgewise and subject to increase in thickness during the bending operation, which comprises bending said material about a form to complete the turns successively, and removing from one face of the bent portions of said turns excess thickness from all portions thereof through an operation which is continuous with the bending operation.

41. In a machine for bending strip material edgewise, a non-circular form having a curved portion and rotatable about a single axis, a bending tool cooperative with strip material to be bent, and means for rotating said bending tool about the curved portion of said form to cause said tool to bend said material to desired shape about said curved portion of the form during rotation of said form.

42. In a machine for bending strip material edgewise, a form having a plurality of arcuate portions connected by a substantially straight portion and rotatable about a single axis, a bending tool rotatable about an arcuate portion of said form and cooperative with the strip material to be bent, and means for rotating said bending tool about said arcuate portion of said form to bend said material to the shape of said arcuate portion during rotation of said form in a direction opposite to the direction of rotation of said bending tool.

In testimony whereof, the signature of the inventor is affixed hereto.

WILLIAM C. FURNAS.

CERTIFICATE OF CORRECTION

Patent No. 1,655,997. Granted January 10, 1928, to

WILLIAM C. FURNAS.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 6, line 74, claim 12, after the word "to" first occurrence insert the word "be"; same page, line 124, claim 16, after the word "form" strike out the period and insert a comma; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of February, A. D. 1928.

M. J. Moore,
Acting Commissioner of Patents.

Seal.