Fig. 17

- Chopper Pre. Amp.
- Power Amp.
- Servo Motor
- Tach.
- Selector Switch
- Holding Relay
- Control Box
- Motor Control
- D.C. Motor
- Needle
- Work Edge
- Kickout Cell
- Guidance Cell
- Bias Supply
- Foot Switch
- Stop-Needle Up
AUTOMATIC WORK GUIDANCE MECHANISMS

This invention relates to the provision of improved means for automatically guiding a work piece in predetermined manner with respect to a tool for operating thereon. More especially the invention is concerned with automatic mechanism for steering generally flat, flexible material progressively to a reciprocable or other tool so that the operating path of the latter will extend in a selected course, for instance substantially parallel to a selected line or plane of curvature such as that of an edge of the material even though such line or plane of curvature be of changing curvature. Although the invention as herein illustrated is embodied in a sewing machine wherein the reciprocable tool is in the form of a needle for securing a binding strip in parallel relation to the edge of the work, another and considerably more specific object of this invention is to provide a machine for automatically and progressively securing as by means of a seam, in edge to edge relation, the upper of a shoe and a piece or strip such as an edge binding. In accordance with these objects and as illustrated herein, a feature of this invention resides in the combination, in a machine having a reciprocable work engaging tool and mechanism for feeding the work in the intervals when the tool is disengaged, of independent means automatically effective between said feeding intervals predeterminedly to steer the work by turning it about its locality of engagement with the tool, the steering means being responsive to selected curvature such as that of the periphery of the work just ahead of the tool. While the tool may, for instance, be an actuated punch, fastener inserter, embosser or marking tool, or other instrument of movable type for physically operating on the work, it will be appreciated that the term "tool" as herein used is intended also to comprehend non-moving elements arranged to engage the work and treat it. Examples of such elements being a cement applying nozzle, a burnishing member or the like. In the illustrated machine the exemplary tool, as above stated, is a reciprocable needle, and hence the work steering means of this invention preferably operates solely while the needle is penetrating a work piece to exert forces for bodily pivoting the latter only about the needle in its successive work engaging localities. Advantageously, the work steering means is adapted to be installed in a sewing or other machine of otherwise conventional construction, the illustrated post sewing machine incorporating a common form of orbital dog feeding mechanism for advancing the work in step-by-step translation in the intervals when the needle is withdrawn from the work. In partial resemblance to the above-mentioned Schaefer et al., disclosure, the present steering means includes a servo-controlled reversible, variable speed steering wheel, the present novel construction, however, in a simple and unique manner, avoiding any necessity for providing a mechanism for this wheel which must differentially allow for the translatory feed speed as affected by the feed dog and its cooperative presser foot.

A further feature of the invention consists in the provision, in a machine having an operating tool and feed means cyclically operative to advance the work by increments, of improved automatic work steering means including only a single steering wheel and a presser member which is arranged to be moved into and out of cooperative work engaging position inwardly of the feed means from the tool, the mounting of the steering means being such that its operation is responsive to that of the feed means and automatically affected in alternation therewith. Advantageously, this construction permits a servo motor controlling velocity of the wheel to operate with zero error during straight line feeding of the work in translation. As herein shown the feed presser foot preferably is a roll carried by a usual vertical, downwardly urged, presser post, and the steering gear system is preferably a roll carried by a lever pivotally connected to the presser post and spring urged into operative position. Thus, advantageously, the steering wheel may be continuously driven regardless of the relative position of the steering presser roll, this position being determined by that of the feed presser roll, and the controlling servo being continuously responsive to changes in selected governing curvature such as edge curvature of the work at a locality immediately ahead of the operating zone of the needle.

The above and other features of the invention, including means for automatically changing incremental feed...
or stitch length without interrupting operation of the machine, and means for sensing a selected work corner automatically to effect stopping of the machine or simply discontinued steering but continued feeding (for instance as a new work piece is being introduced to the machine), together with other novel combinations and arrangements of parts will now be more particularly described in connection with an illustrative machine and with reference to the accompanying drawings thereof, in which:

FIG. 1 is a view in front elevation of a post type sewing machine, at rest, for securing binding strips to articles such as shoe uppers and in which this invention is embodied;

FIG. 2 is a view in front elevation, partly in section, showing on a larger scale and in operating condition the sewing machine head and post together with automatic work guidance means including a steering wheel and cooperative steering presser roll;

FIG. 3 is a view in side elevation of mechanism shown in FIG. 2;

FIG. 4 is a view in front elevation showing operating instrumentalities including a needle as indicated in FIG. 2, on a further enlarged scale, portions being in section to illustrate actualizing means for the steering presser roll;

FIG. 5 is a section taken on the line V—V of FIG. 3 indicating the mountings of a feed presser roll and the steering presser roll;

FIG. 6 is a plan view of the work supporting post indicating the relative positions of the work steering wheel and a throat plate assembly accommodating the sewing needle, a feed dog, and control cells with reference to an adjustable null line and work piece;

FIG. 7 is a section taken on the line VII—VII of FIG. 6 extending through a needle hole;

FIG. 8 is a graph comparing the torque required to turn a given leather work piece in the machine with the torque available from the steering wheel in a cycle of operations;

FIG. 9 is a view in front elevation, with a portion broken away, of the right hand side of the machine and showing stitch length change mechanism;

FIG. 10 is a detail of an axial part in the stitch length change mechanism;

FIG. 11 is a section, on a larger scale, taken on the line XI—XI of FIG. 9;

FIG. 12 diagrammatically indicates a work piece portion having an edge of inside curvature at which stitch length, merely because of such curvature, normally is increased;

FIG. 13 shows the same edge as shown in FIG. 12 but with stitch length reduced actually to provide more uniformity in stitch length appearance and an increased number of stitches at the curvature;

FIG. 14 is an end elevation, partly in section, illustrating means for automatically stopping the machine with its needle in up position, the parts being shown in position when the machine is stopped;

FIG. 15 is an end elevation corresponding with the upper portion of FIG. 14;

FIG. 16 is a section taken on the line XVI—XVI of FIG. 14;

FIG. 17 is a block diagram of the work guidance system and associated electric machine controls;

FIG. 18 is an electrical diagram of power amplification and preamplification units as connected between the guidance control and a servo motor;

FIG. 19 is an electrical diagram complementary to that of FIG. 18 and showing motor and bias supply controls; and

FIG. 20 is an alternate form of steering presser foot as mounted for cooperation with the steering wheel of this machine.

General Organization

In many respects, unless otherwise noted herein, the sewing machine illustrative of the invention is of a commercially available construction and consequently adaptable to receive automatic work guidance means as will be described. It comprises a hollow frame 22 (FIGS. 1–3) secured on a bench 24 and having a vertically reciprocable needle 26 (FIGS. 1–4). In guiding the work in the machine by the exercise of this invention and without operator attendance once the work has been presented, the operating path of the needle on the work may be caused, as will be explained, to extend in any selected course.

For purposes of illustration a work piece, such as an upper U (FIGS. 1 and 6) of a shoe, is automatically guided with respect to the needle 26 to cause the stitches of a seam to extend parallel to a work piece edge thus securing an article such as a binding strip S (FIGS. 1 and 3) in parallel edge relation. The needle is disposed to be received in a needle hole 28 (FIG. 6) of a bobbin cover or throat plate 30 screwed onto the upper end of a composite machine post 32 (FIGS. 1–3 and 6) upstanding from the bench 24. As usual for operating the needle the frame 22 supports in bearings a horizontal main shaft 34 (FIGS. 3 and 9) operatively coupled to a needle post 36 (FIGS. 1–5) vertically reciprocable in a bore formed in an overhanging head 38 of the frame 22. The main shaft 34 and an orbitally actuated feed dog 40 (FIGS. 3, 4 and 6) are driven from a main D.C. motor 42 (FIGS. 1, 9, 17 and 19) through mechanism subsequently described.

It will be understood that the feed dog 40 intermittently rises above the level of the supporting surface of the throat plate 30 to feed the work step-by-step in translation past the needle in the intervals when the latter is disengaged from the work, the direction of feed being from right to left in FIG. 3 or from bottom to top as viewed in FIG. 6. For cooperating with the feed dog a feed presser roll 44 (FIGS. 2, 4 and 5) is carried by an end of an arm 46, the other end of which is secured to a bracket 48. This bracket is fixedly mounted by means of a set screw 50 (FIG. 5) on the lower end of a presser foot post 52 (FIGS. 3, 4 and 5) arranged for movement in a vertical bore formed in the head 38. In usual manner the feed presser roll 44 is yieldedly urged toward work-engaging position when the post 52 is in its lower position, a spring 54 (FIG. 5) having its lower end bearing on a bracket 56 affixed to the post and an upper end abutting a sleeve 58 adjustably threaded in the head 38. A hand lever 60 (FIG. 3) pivoted to the head at 62 has an end surface 64 disposed to engage a horizontally projecting portion of the bracket 56 as the lever is turned clockwise as viewed in FIG. 3 for the purpose of raising the post and the feed presser roll 44 from the work. As indicated in FIG. 3 by dotted lines the surface 64, when horizontal, latches the post 52 in its upper and inoperative position.

Work-engaging pressure of the roll 44 may be modified by suitably turning the sleeve 58, some slight pressure normally being desirable for a given thickness of the work, even while the dog 40 is in lowered position and disengaged from the work, though this pressure should not be enough to affect work guidance by means hereinafter explained.

A reel 66 (FIG. 1) for holding a supply of the binding strip S is to be secured to the shoe upper U (FIG. 6) is rotatably mounted in a holder 68 removably secured to the machine head. The strip extends downwardly through a guideway 70 (FIG. 1, 3 and 5) formed on the front end of a bracket 72 secured to the presser post bracket 48, the exit end of the guideway being disposed somewhat ahead of the needle hole 28 and laterally spaced to aline an edge of the strip with a peripheral edge of the upper in a locale about to be stitched, both edges then being close to, if not exactly in, tangency with a null line L (FIGS. 5 and 6) determined by automatic guidance means next to be explained.
This guidance system comprises a single steering member in the form of a work engaging wheel 80 (FIGS. 2, 4 and 6), a steering presser member shown as a roll 82 arranged to cooperate therewith, and electrical means including a servo motor 84 (FIGS. 1-3, 17 and 18) for controlling the velocity of the wheel 80, the servo motor being under the continuous command of curvature sensitivity mechanism to be described. The wheel 80 is journaled in an upright wall 86 (FIGS. 2 and 3) within the machine post 32 and has an upper portion of its toothed periphery projecting through a slot 88 (FIG. 6) of the post for frictional engagement with the underside of the upper U. As best shown in FIG. 6, the wheel 80 is thus arranged to engage the work at a locality spaced inwardly from the work from the needle operating zone than is the feed dog 40, the work engaging localities of the needle, dog, and steering wheel lying substantially in a line normal to the null line L. For operating the wheel 80 a bracket 90 (FIGS. 2 and 3) secured to the underside of the top of the bench 24 mounts a housing 92 for suitable reduction gearing (not shown) having output shafts 94, 96 which are universally coupled. Accordingly, the servo motor 84 together with its stabilizing tachometer generator 98 (FIGS. 17, 18) is mounted on the housing 92 reversibly to drive the shaft 96 and a bevel gear 100 on the upper end thereof which meshes with a bevel gear 102 formed coaxially on the steering wheel 80.

The curvature sensing means above referred to for continuously governing speed and direction of the servo controlled steering wheel 80 is, in this case, arranged to sense curvature of the edge of the upper itself at a locality just ahead of that about to be acted upon by the needle 26. The means comprises electrical circuitry including a light sensitive device in the form of a work sensing or guidance solar cell 108 (FIGS. 6, 17 and 18) embedded in the throat plate 30, a D.C. bias supply unit generally designated 110 (FIGS. 17 and 19), a preamplifier unit generally designated 112 (FIGS. 17 and 18), and a power amplifier unit generally designated 114. Location of the cell 108 is critical to servomotor stability and important to derive accurate steering or "error" signals. Preferably the cell is spaced within a range from substantially zero to one-eighth the diameter of the needle hole 28, the best location usually being within about one-eighth of the cell is covered by the work piece acting as a shutter, and the other half of the cell 108 is exposed to light beams directed from a source above, such as a bulb 116 (FIGS. 1, 2 and 4) mounted on the bracket 48 or, if preferred, simply dependent from the head 38. By reason of change in curvature of the work piece edge at a point closely adjacent to the operating locality as the upper is fed past the needle, the cell 108 is more or less covered by the upper U. Accordingly, a D.C. voltage from the curvature detecting cell, generated when the cell is covered exactly to the null line L by the upper, is directed to one leg of a resistance circuit within the preamplifier unit 112 and nullled by application of a D.C. voltage, equal in magnitude and polarity, from the bias supply 110 to a second leg of the resistance circuit, a third leg of this circuit including a variable resistor 118 (FIG. 18) having a manual control 120 (FIG. 1) for fine adjustment of the null point or line L as desired. The electrical null and consequently the steering null line L are established by the fact that voltages equal in magnitude and polarity are present in the two resistance circuits in the preamplifier 112 and that the electromechanical chopper unit of the preamplifier 112 alternately reads the voltage present in the two resistance circuits. The electromechanical chopper unit of the preamplifier 112 directs these voltages to a coupling capacitor 121 (FIG. 18) of the preamplifier 112 which filters the chopper ripple signal, which is undesirable particularly at the servomotor null point, to give only a system reference voltage and therefore no net error signal. Each increment of feed is therefore likely to change the voltage present in the resistance circuit connected to the cell 108 and thereby creates a net voltage difference as "seen" by the capacitor 121 constituting an error signal. The servomotor 84 is driven upon error signal voltage phasing for direction of rotation information. This information is supplied by virtue of the fact that the net voltage difference producing the error signal must be larger than the system reference voltage and that this difference may alternately appear at the electromechanical chopper contact, connected to bias supply 110 resistance circuit, or the contact connected to the cell 108 resistance circuit, as the cell 108 is either covered more or uncovered more. This signal, which is now an A.C. signal by virtue of the electromechanical chopper, is amplified and is passed through a contact KICI (FIG. 18), when closed, to a functional control box generally designated 122 (FIGS. 1, 17 and 19). The contact KICI is closed by actuation of a foot switch 124 (FIGS. 1, 17 and 19) to energize a relay coil K1 shown in FIG. 19 and, in fact, mounted on the chassis for the preamplifier unit 112. After appropriate switching in the circuit the functional control box 122 the error signal is fed to the power amplifier unit 114 and ultimately to the servomotor 84 itself. As will be understood by those experienced in servomotor art, the so-called "pure" error thus derived is modified in known manner for damping purposes by employing the tachometer generator 98 to add a rate of change of error signal, the addition being effected by a variable resistor and a summing resistor in the preamplifier unit 112. Also, in known manner, other components of the preamplifier unit enable the servomotor 84 to achieve maximum power by insuring the voltages in its control and reference windings are in quadrature.

As has been indicated, while the steering wheel 80 is continuously operative and hence always potentially able to exert a steering torque on the work, it desirably is actually effective to guide or steer the work only when the needle 26 has penetrated, in this case, the upper and strip S and can thus serve as the pivot or instantaneous center of turning about which the work is bodily swung by the wheel. For thus causing the steering to be effected alternately with each increment of feeding, and synchronously with successive work engagements of the needle, mechanism next to be explained is provided for automatically causing the steering presser roll 82 to be urged into an effective torque exerting position of greater cooperative work engaging pressure and then retracted to a substantially ineffective position wherein its work engaging pressure is minimal permitting slippage of the wheel 80 and substantially no effective guidance torque. Experiments have shown that the wheel 80 will slip on most upper leather, for instance, when the guidance torque is reduced to about 10 inch-ounces or less (see FIG. 8). The roll 82 is carried on the front end of a lever 130 (FIGS. 3 to 5 inclusive) pivotally secured by a fulcrum pin 132 to the bracket 48. The rear end of the lever 130 is connected by means of a tension spring 134 to the lower end of a stud 136 adjustably threaded heightwise in a tubular support 135 secured to the machine head 30. A knurled head 140 on the stud 136 may be rotated suitably to modify the clamping pressure (and consequently the torque level before slippage) exerted by the steering presser roll 82 according to the severity of curvatures involved in the operating path of the needle and with regard to the character of the material to be guided. A collar 142 (FIG. 4) pinned on the stud 136 aids in guiding it heightwise in the support 138 which is vertically slotted as shown in FIGS. 1 and 2 to accommodate the lever 130. The importance of the mechanism just described for effecting work guidance alternately with each step in work
feeding is emphasized because it economically enables the guidance system, after each feeding increment, bodily to turn the work to the correct degree about the spring engaging needle 78 to maintain the full error signal is nulled or reduced to zero; hence upon upward retraction of the needle the thread of the stitch next to be inserted following the feeding increment will lie in accurately parallel relation to the work edges. It will be understood that when the feed dog 40, acting through the work, lifts the feed presser roll 44 in the course of a feeding increment, the steering torque available from the wheel 80 is reduced substantially as shown in FIG. 8 since resultant raising of the presser foot post 52 and of the fuller pin 132 relieves the upward force exerted by the spring 134 and hence correspondingly reduces the work-engaging pressure of the control curve, such as 82, to allow ineffective rotation of the wheel 80. Consequently the required servo response frequency is not equal to the incremental feeding frequency of the feed dog 40 but is only a function of the equivalent frequency as generated by the radius of curvature and the average peripheral speed of the work. Thus, the required servo response frequency may be many times less than the incremental feeding frequency. Considered further with reference to FIG. 8, when the feed dog 40 is being lowered at the end of a feeding increment, the wheel 80, by reason of the now increasing work clamping pressure exerted by the spring 134 through the steering presser 82, is ready and able to exert a steering torque theoretically limited only by the output of the servo motor 54.

Machine Drive Mechanism

In addition to the automatic work guidance system described, the illustrative machine includes in highly advantageous combination therewith and as parts of its drive mechanism next to be considered means generally designated 148 (FIGS. 9–11 and 13) for changing stitch length, particularly in the case of traversing sharper inside curves as shown in FIGS. 12 and 13, without interrupting operation of the machine, and a device generally designated 150 (FIGS. 9, 14 and 16) for automatically stopping the machine with its operating tool, the needle 26, in up or inoperative position. First with regard to the means 148, on the main shaft 34 is hollow to receive a conically ended portion 152 (FIGS. 10 and 11) of an axially slidable operating shaft 154 (FIGS. 1, 9 and 11). The latter as indicated in FIGS. 14 and 16 extends axially through a hand wheel 156 keyed on the shaft 34, and through parts of the device 150 comprising a cam 158 rotatable on a reduced hub of the hand wheel, 160 a pulley 169 to which the cam 158 is keyed, a cam plate 162 straddling the cam, and a guide plate 164 having opposed, parallel walls 166, 168 for guiding the cam plate 162 as displaced by the cam 158. The guide plate 164 is bored to receive a pair of pins 168, 168 (FIG. 16) for securing the plate 164 to the hand wheel. A pulley 170 (FIG. 9) on the drive shaft of the motor 42 is fitted with an endless belt 172 for transmitting power to the pulley 160. For changing stitch length at the will of the operator, he shifts the shaft 154 to the right as viewed in FIG. 9 by any suitable means, a knee pad 174 (FIGS. 1 and 9) being provided in this case for this purpose. Thus actuation of the pad to turn its carrying lever 176 counterclockwise as viewed in FIG. 9 about a fulcrum 178 provided by a bracket 180 secured to the bench operates linkage including an arm 182 of a lever 184, and a link 186 connecting the arm 182 to the lower end of a long vertical lever 188. The upper end of this lever 188 is pivoted to a bracket 190 (FIGS. 1, 9 and 15) secured on the main frame, and is connected by trunion pins 192, 192 to a collar 194 affixed on the shaft 154. This shifting of the shaft 154 is effected against resistance of a return spring 196 connecting the bench and the lever 184.

Referring mainly to FIGS. 9 and 11, actuation of the pad 178 axially to shift the conical portion 152 as just described causes this portion to bear on a pointed end of a plug 192 and causes the rounded end of the plug 192 to be inwardly into an enlarged hub portion 200 of an eccentric 202, the plug extending radially through a bore formed in the wall of the main shaft 34. Accordingly, the hub portion 200, which is mounted on a pivot pin 204 projecting from a flange of a collar 206 secured on the shaft 34 and having a plurality of notches 208, is free to rotate in a clockwise direction as viewed in FIG. 11 by means of a spring-pressed plunger 208 bearing on the shaft 34 at a locality diametrically opposite to the plug 190. The eccentric 202 is therefore shifted to a position of greater concentricity with the shaft 34 to the limit adjustably permitted by a short friction adjusting screw 210. For this purpose the screw 210 extends into one end of an accurate slot 212 (FIG. 11) formed in the hub portion 202 for endwise engagement with a stop screw 214 threaded through the flange of the collar 206 at a locality diametrically opposite to the pivot pin 204. The displacement to lessen eccentricity of the eccentric 202 will be understood, is effective to shorten the stiches by reason of shortening the throw of a connecting rod 216 (FIGS. 3 and 9) for rocking a customary sewing machine feed shaft 218 (FIG. 3) horizontally mounted in the bench 24. As usual a crank 220 secured on the shaft 219 causes a lever 222 (FIG. 3) to impart feeding movements to the needle 26, to the dog 40, its heightwise movements being concurrently imparted by a rotary cam 224 working in a forked arm 226 of the lever 222.

FIG. 11 depicts the screws 210, 214 in their operating positions, for instance before negotiating the curvature indicated in FIG. 13, whereby the stiches have been shortened and hence adjustably increased in number. Without means to change to shorter stitch length at sharper inside curves it is found that their length is, in fact, otherwise lengthened as shown in FIG. 12 thereby producing unsightly, nonuniform appearance in the product. Shorter stitch length at such curvature yields better construction and a binding of better appearance, for instance, when the strip S is later folded over. Release of the pad 174 permits the spring 196 to restore the normal stitch length without interrupting operation of the machine, the stop screw 214 turning to a long stich adjusting screw 228 (FIG. 11) threaded through the portion 202 and into the opposite end of the slot 212.

Now more especially to the device 150 for stopping the machine in needle-up position, it is essential for decreasing the operating time of a machine cycle and permits positioning of the lever 188 to correctly locate the machine before commencing automatic operation. The device is adapted to terminate rotation of the main shaft 34 in a position corresponding to that in which it has raised and retracted the needle 26 from the work. A motor control unit generally designated 230 (FIGS. 1, 17 and 19) includes a variable 252 (FIG. 19) for changing A.C. voltage applied to a rectifying bridge 234 which, in turn, provides a D.C. voltage to the motor 42 as selected by means of a knob 236 (FIG. 1) for thus controlling variable speed of the motor. The latter is energized for operation at the preselected speed by actuation of the foot switch 124 to energize contacts K2 and K5 (FIG. 19), resultant A.C. voltage being applied to a rectifier bridge 238 through a contact K5A1 and directed as D.C. voltage through contacts K2A1 and K2A2 to the motor. Cutting off of the motor drive voltage by means of the device 159 as now explained stops the shaft 34. The release or opening of the foot switch 124 the relays K1, K2 and K5 are deenergized, and a relatively low A.C. voltage is accordingly applied to the rectifier bridge 238 through a new closed contact K5B1 (FIG. 19). This gives rise to a D.C. reversing voltage being applied to the motor 42 through now-closed contacts K2B1 and K2B2. Accordingly, when the machine has stopped and its main shaft 34 starts to reverse (i.e. turns in the clockwise di-
rection indicated in FIG. 14), the cam plate 162 is outwardly displaced radially until its projection 240 (FIG. 14) depresses a striker 242 pivotally carried by a lever 244 itself pivotally secured on a pin 245 in a bracket 246 which is affixed to the right-hand end of the machine frame 22. The arrangement is such that a projection 240 (FIGS. 9 and 14) on the lever 244 consequently opportunely switches a switch 250 (FIGS. 9 and 14) removing all motor drive voltage immediately to stop the machine in needle-up position. Better to understand this operation of the device it is pointed out that the cam 158 is formed with a rise 252 extending over an arc of 60°. During forward or sewing operation of the shaft 34 (counter-clockwise rotation as viewed in FIG. 14), the torque required from the cam 155 reacts against an internal wall 254 of the cam plate 162 causing it to retract inwardly in the guide plate 164 with the switch operate projection 240, the latter then being ineffectual while pivoting the projection 240 clockwise (as viewed in FIG. 14) against the resistance of a spring 255 which normally holds the striker against a stop 257 formed on the end of the lever 244. When fully retracted, the cam 158 is in driving or forward feeding engagement with the internal cam plate wall, but upon motor reversal as has been stated, the cam 158 acting upon an internal wall 256 of the pin 245 to quickly displace the cam 254 outwardly consequently depressing the striker to switch opening position. It will be apparent from FIG. 14 that the switch 250 is permitted to assume its normally closed position during machine operation by a spring 258 connecting the lever 244 to the bracket 246, the spring serving to urge the striker 242 into position to be engaged by the projection 240 upon motor reversal.

Work Controls Adjacent to Guidance System

As shown in FIG. 1 the control box 122 (FIGS. 1, 17 and 19) in which the control switchboard 124 is mounted also includes a manual stop switch 252 and a rotary selector switch 264. The latter is advantageously employed to select any preferred one of four modes of operation of the machine next to be explained according to whether this switch is turned to its position 1, 2 or 3 indicated on the box 122. In switch position 1, used for normal operation, the machine drive and work guidance is controlled solely by the foot switch 124 as described.

The second mode is followed when it is desired to have operation of the machine automatically stop at the "end" of each work piece, i.e. at the finish of a closed path of operation as a "corner" or sharply curved in the curvature in the curve being sensed approaches a position closely adjacent to the operating zone of the tool or needle, or approaches a control position corresponding thereto. For this second mode, known as "feed out" or "kick out," the switch 264 is set in the position 3 to energize control circuitry which includes a light sensitive device in the form of a silicon solar cell 266 (FIGS. 6, 17 and 19). This cell is embedded in the upper surface of the throat plate 30 immediately ahead of the guidance cell 168 and preferably disposed parallel to the operating path of the feed dog 40. Referring to FIG. 19, in practicing this automatic work kick out feature, a switch S2 now being closed, a switch S3 being open, and a switch S4 being closed at position B, the foot switch 124 is held depressed to cause the machine to operate as previously described, the motor 42 continuing to run by virtue of energization of the relay K3 and consequent closure of a contact K3A1 which engages the foot switch 124. When the beam being inserted has been guided past some selected "corner," for instance the next to last one, the operator will release the foot switch 124, and a voltage is thereby applied to a transistor amplifier 268 and to a coil 266, the machine continuing to run under the automatic work guidance system of FIG. 19, until the cell 266, upon being uncovered by the work at its next, i.e. "last," corner, an added voltage surge is applied to the relay K4 via the transistor amplifier 268, and the relay K4 then opens a contact K4B1 (FIG. 19) to deenergize the relay K3 thereby removing the braking voltage to stop the machine with its needle in up position. It will be appreciated that this second mode of operation provides added freedom for an operator; he may, during the final stage of automatic guidance on one work piece, as soon as he has released the foot switch, reach for the next piece to be processed for instance, being assured that the machine will automatically cease operation at the correct point, for example at the locality where the seam was initially started.

In a third mode of operation now to be explained and termed the "kick off" function, the selector switch 264 is also at position 3. This mode is used in connection with peripheral operations when it is desirable to terminate operation of the machine at any point along the operating path other than at a corner. When the point is reached a manual kick off switch 272 (FIGS. 1 and 19) is actuated. This results in a signal being transmitted via the closed contact B of the switch S4 to a line designated D and hence to the power amplifier 114 causing the servo motor forthwith to steer the work away from the operating zone. This is to say that the resultant overriding command to the servo motor results in the wheel 50 to rotate to turn the work rapidly clockwise (as viewed from above) about its own axis and the machine consequently stops when it has thus caused the work to render the cell 266 exposed to light from the bulb 116.

A fourth mode of operation is advantageous in speeding up output, particularly when smaller work pieces are being processed, and is termed the "kick through" arrangement. For this purpose the selector switch 264 is adjusted to position 2 (FIG. 1) causing the switches S2 and S3 (FIG. 19) to be closed, and a contact A of the switch S4 to be closed while its contact B is open. In this mode the main motor 42 is permitted to run continuously as the work pieces are successively guided and sewn, one directly following completed guidance of another. The relays K1, K2, K3 and K5 are energized by actuating the switch 124 and the motor 42 drives by virtue of the closure of the contact K3A1. Prior to sewing the feed out corner the switch 124 is released to energize the coil K4 and the transistor amplifier 268. As the kick out cell 266 senses the "end" of each work piece (in the manner described for the second mode), the cell applies a surge through the transistor amplifier 268 further to energize the coil K4 and close a contact K4A2. As a result power is now fed from an independently powered circuit including a potential meter 274 (FIG. 19), via the contact K4A2 and the line D, to the power amplifier 114 instead of an input from the pre-amplifier 112, the velocity of the wheel 80 thus being modified to permit the feed dog 40 to operate forthwith to feed the work in a substantially straight line away from the operating zone. Now, when the operator presents the next work piece thereby again covering the cell 266, the contact K4A2 opens and the contact K4B2 closes to transmit the normal guidance error signal from the pre-amplifier 112. To stop the drive motor 42 the switch 262 must be actuated when the series of work pieces has been processed.

FIG. 20 illustrates an alternate type of steering presser in the form of a bowed or U-shaped spring 250 which may be substituted for the steering presser roller 82 in frictionally exerting, cooperatively with the steering wheel 90, suitable steering torque on the work. The spring 250 is secured at its ends to a horizontal bracket 282 fast on the head 35, lies in a vertical plate, and has a mid portion 284 movable heightwise in yieldable work engaging position. The width of the spring portion 284 is preferably at least as great as that of the toothed perimeter of the wheel 80 and, notably, is yieldable in translation parallel to the direction of feeding. If desired, of
course, opposed margins of the portion 284 may be rounded upwardly from the work. For automatically guiding work, the feed of the portion 284 is mounted to be movable heightwise together with the feed presser roll 44 by the post 52. Thus, a yoke 286 attached to the portion 284 is connected by a coil spring 283 to one end of a lever 290, the other end of which is pivotally secured by a screw 392 to a block 294 clamped on the post 52. Means including a vertical set screw 296, a pivotal lever 298, and an eccentric cam 300 manually adjustable by a control knob 302 are provided for obtaining differential in operating pressure between the feed presser roll 44 and the spring 280.

**Machine Operation**

It will be understood that the machine is provided with a supply of thread T (FIG. 1) for the line of sewing to be inserted by the needle 26 as determined by the automatic work guidance mechanism above described. Also, it will be understood the usual shuttle mechanism (not shown) is mounted in the post 52 and operated from a drive belt 394 on a pulley 396 (FIG. 9) secured on the main shaft.

By means of the knob 296 the operator will first have controlled the motor speed with which the seam is to be inserted. Having connected the machine and controls to their respective power sources an operator places the upper to be sewn on the machine post 52, lowers the presser foot post 52 by means of the lever 60, and, while ascertaining that the end portion of the strip S is extending suitably from the exit of the guideway 70, holds the extremity of the thread T for the first stitch as he actuates the treadle 124. Without further attention the sewing machine then continues to operate, alternating steps of translatory work feeding and automatic steering, the latter being dictated by the curvature of the work edge, until the work piece has traversed the desired course and is automatically ejected. The resultant seam securing the upper and strip in parallel edge relation will extend parallel to the edge the curvature of which is being sensed by the cell 108. Feeding in straight line translation is effected by the dog 40 in approximately half the machine cycle, the other half being used at least in part for steering by means of the wheel 80. In the steering intervals, which normally occur only when the needle has engaged the work to serve as a turning center therefor, the wheel 80 is caused by the servo motor 84 to rotate with a torque frictionally applied to the work. A servo motor could conceivably be electrically controlled so that its output would be synchronized in a cycle with the work engaging phase of the needle, but since this appears to necessitate the use of unduly expensive equipment, this invention provides for the servo motor 84 continually to receive steering signals, but at practically no added cost effectively couples the output of the servo motor to the work via the wheel 80 only while the needle is engaged. This is accomplished by making use of the heightwise movement of the feed dog 40 to control alternation of feeding and steering. Thus, when the feed dog moves up to feed, it acts to lift the work off the steering wheel 80, or (if the work be less stiff) acts through the post 52 to reduce the pressure with which the work is engaged at its steering locality by the wheel 80 so that the latter then rotates harmlessly and is temporarily ineffective. On descent the dog returns the work to be coupled to the wheel 80 for steering about the now engaged needle.

And thus produces a signal, which varies from the D.C. reference voltage from the bias supply 110, which corresponds with deviation of the controlling curvature, in this case the work edge, from its correct position. Accordingly, a signal in terms of D.C. voltage is derived to be converted to an A.C. signal which, when amplified and clipped as explained, is fed to the servo motor 84. The latter therefore reversibly and continuously drives the steering wheel 80 in the proper direction and with correct speed potentially to apply a moment to the work U to restore it to its correct or zero error position after each increment of feed in translation effected by the dog 40.

Considered analytically, error or deviation of the machine will vary according to the requirements of particular work, it being helpful in some cases to provide the steering presser roll 82 and/or the wheel 80 with a periphery of a rubber-like, friction-enhancing material. In the illustrative machine a short interval may occur in the cycle in which it is possible that, although the needle 26 is still descending or has just descended into the work, the wheel 80 may be exerting a low torque but be ineffective to steer the work by reason of the fact that the dog 40 is still engaging the work with sufficient clamping pressure to cause the wheel 80 simply to slip. It should be noted, however, that the preferred timing and organization of the work-clamping pressure of the feed means, i.e., the dog 40 and the roll 44, is capable of exerting torque to steer the work either about the needle or the work engaging locality of the wheel 80. In other words, as indicated in FIG. 9, the feeding and steering portions of a cycle are normally exclusive, steering occurring only when the needle is disengaged or at least causes no appreciable drag. Slight exception may occur in some machines when there advantageously is a very brief overlapping of the feeding and steering functions by reason of a small work engaging pressure being allowed to be exerted during steering time by the feed presser, for instance where feeding is phase dispaced from needle motion. The feed presser is then providing a light drag or pivot to enable the needle to pierce the work just before the feed stroke is complete; in this situation the needle is still out of the work when steering action commences.

In conjunction with the automatic work guidance means provided, the several control features above explained have been found particularly helpful, both individually and collectively, to the operator. Thus, by means of the device 150 the needle 26 never interferes with proper loading or removal of the work from the machine, the mechanism depicted in FIG. 14 operating as explained, reliably to lift the needle from the work almost instantly when the treadle 124 is released to stop the machine. Also, during continuous operation of the machine on the work being automatically guided, it is found advantageous to employ the stitch-length changing mechanism at a selected portion of the operating path. As explained with reference to the FIGS. 9–11, the operator only needs to actuate the knee pad 174 as the selected portion (the sharp inside curvature of FIG. 13, for instance) approaches the operating zone of the needle, to shift the shaft 154 axially to the right (in FIG. 9) and thus shorten stitch length. This makes for a stronger seam in a critical area and produces a more uniformly stitched article.

Selection of one of the three settings 1, 2, or 3 for the selector switch 264 enables the operator to have the work automatically guided in the machine to the selected ejection or stop position. As above explained, the resultant circuitry causes kick-off, kick-through, or kick-off. In the kick-out mode, the switch 264 being in position 3, the operator simply releases the switch 124 as the work is being guided to cause the next or "final" corner to approach the ejection control cell 266. Upon this corner uncovering the cell 266, it causes the drive motor voltage to be cut off and the machine to stop in needle
up position, the work being ejected if it was the "last" corner traversing the cell 266. Normally, of course, the switch 124 may be released at any time simply to stop operation of the machine.

In the kick-through mode, the switch 264 being at position 2, when the foot switch 124 is released the machine continues its normal automatically guided sewing until the "last" work corner advances and sufficiently uncovers the cell 266, whereupon the dog 40 feeds the work straight from the needle to permit the next piece of work to be presented thereto without interrupting operation of the machine. The kick-off mode permits immediate feed-out of the work upon manual operation of the switch 272. It will be understood that the thread T and strip S will be severed as convenient to provide the individual, assembled work pieces.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. In a machine having a tool for operating on a work piece, mechanism intermittently operative to feed the work piece an increment in translation past the tool, and edge curvature controlled means adapted to initiate and exert a steering torque on the work piece and about the operating locality of the tool each time the feeding mechanism has operated to determine the operating path of the tool on the work piece.

2. In a machine having a work support, a relatively movable tool for operating on successive portions of a work piece on the support, means for feeding the work intermittently in translation with respect to the tool, a work sensing circuit, and automatic guidance means continuously responsive to said circuit and frictionally operable in time relation to the work feeding means for controlling steering movement of the work piece with respect to the tool.

3. In a machine having a work support provided with an operating zone and on which a work piece is intermittently advanced in translation one step beyond said zone, a relatively movable tool cooperative therewith at the operating zone by engagement with successive portions of a work piece, automatic guidance mechanism including a member frictionally engageable with the work piece at only a single locality spaced from the tool for steering the work piece with respect thereto, and means for causing said guidance mechanism effectively to operate when the tool is operative in said zone.

4. A machine having a tool for operating on successive portions of a work piece, a work support on which the work piece is to be guided with respect to the tool by operation of work feeding means and work steering means, said feeding means including a member having components of movement both heightwise and in translation, curvature sensing means for controlling said steering means, and mechanism responsive to one of the components of motion of said member for effectively operating the steering means alternately with the feeding means.

5. In a machine having a tool for operating on or near the margin of a work piece and means for feeding the work piece step-by-step past the tool, mechanism engageable with the work piece at one locality only for steering the work with respect to the tool according to the curvature of the work edge in the operating locality of the tool, and means for effectively operating said steering mechanism said feeding means for said work piece to feed it in translation when the tool is retracted, a presser arranged to cooperate with said feed member by engagement with the work piece on its opposite side, mounting means for said presser yielding to effect its work engagement during tool retraction, and work guidance mechanism comprising a continuously operative steering wheel and cooperative steering presser arranged, respectively, to engage the work piece inwardly of the feed member, the velocity of said wheel being controlled by sensing means responsive to change in curvature of said edge in the vicinity of the tool, and the steering presser having operative connection to said mounting means effectively operating said steering mechanism when said feeding means is inoperative.

7. In a machine comprising a tool adapted to engage successive marginal portions of a work piece and having means for advancing the work piece past the tool each time the tool is retracted therefrom, work steering means including a steering member and a presser member cooperatively engageable with opposite sides of the work piece inwardly of its marginal means for controlling the steering member according to marginal curvature of the work in a locality just ahead of the tool, and mechanism responsive to operation of the work advancing means for controlling relative movement of the steering and presser members into and out of cooperative work-engaging positions whereby the work steering member is effective bodily to turn the work about the tool only when the tool is in engagement therewith.

8. In a machine comprising a tool engageable with the margin of a work piece and having means for intermittently advancing the work piece past the tool, work steering means engageable with opposite sides of the work piece at only a single locality inwardly of its margin, said steering means being continuously responsive to the curvature of the margin in its portion immediately ahead of the tool, and mechanism for rendering said steering means effective in each interval that the work piece is not being advanced, reversibly to swing the work piece about a turning center substantially at the zone of engagement of the tool therewith.

9. In a machine having a reciprocable tool for operating on a work piece and comprising work feeding means including a first presser member for feeding the work past the tool, automatic work steering means including a second presser member spaced from the first, and control means operative in time relation to the operation of the tool for alternately shifting the presser members into and out of effective engagement with the work whereby the work is alternately fed and steered.

10. In a sewing machine having a reciprocable needle and a throat plate formed with a hole for receiving the same, an orbitally actuated dog for feeding the work past the needle step-by-step, and automatic work steering means including only one pair of work-engaging members for bodily turning the work about the needle when the latter has penetrated the work.

11. A machine as set forth in claim 10 further characterized in that electrical means is provided for controlling the velocity of one of said members in accordance with change in curvature.

12. A machine as set forth in claim 11 and further characterized in that the electrical means includes a circuit comprising a light responsive device arranged in the throat plate ahead of the needle by a spacing in the range of substantially from zero to five feeding steps, and said one member is a wheel reversibly rotatable according to the curvature of an edge of the work.

13. In a machine having a reciprocable tool for operating on successive portions of a work piece, a work support over which the work piece is to be fed and guided with respect to the tool to cause its path of operation to extend in parallel relation to the edge of the work piece, a feed member movable heightwise of the work support for intermittent engagement with one side of the work piece to feed it in translation when the tool is retracted, a presser arranged to cooperate with said feed member by engagement with the work piece on its opposite side, mounting means for said presser yielding to effect its work engagement during tool retraction, and work guidance mechanism comprising a continuously operative steering wheel and cooperative steering presser arranged, respectively, to engage the work piece inwardly of the feed member, the velocity of said wheel being controlled by sensing means responsive to change in curvature of said edge in the vicinity of the tool, and the steering presser having operative connection to said mounting means.
whereby the guidance mechanism is effective to pivot the work piece about the tool only when it engages the work piece.

14. A machine having a reciprocable tool for operating on successive increments of sheet material, comprising a mechanism operable to advance the sheet material rectilinearly an increment between successive engagements of the tool with the material, the guidance mechanism operable for exerting torque on the material at only a single locality spaced from said engagements of the tool, curvature monitoring means for controlling the potential torque to be exerted by the guidance mechanism, and means for causing said torque actually to be imparted by the guidance mechanism to the sheet material only when the latter is being engaged by the tool.

15. In a machine having a tool for operating on successive portions of a work piece, means for feeding the work piece rectilinearly an increment between the successive operations of the tool, and guidance mechanism operative simultaneously with the tool bodily to turn the work piece about the operating zone of the tool when the latter is in engagement with the work piece, said mechanism including a servomotor continuously responsive to signals generated from a controlling pattern.

16. A machine as set forth in claim 15 and further characterized in that the guidance mechanism comprises only one member reversibly driven with variable velocity in frictional engagement with the work piece, the velocity of the member corresponding to the concurrent deviation of the curve of said pattern from the preceding rectilinear feeding increment whereby torque exerted by the member on the work piece seeks to reduce such deviation to zero.

17. In a sewing machine having a reciprocable needle, a throat plate having a needle receiving hole over which work to be sewn is to be guided, means including a member movable heightwise of the throat plate for feeding the needle increment in translation each time the needle is retracted therefrom, work steering means including a wheel and cooperative presser engageable with the work under variable pressure at a single locality spaced from the operating path of the needle and close to the work supporting surface of the throat plate, a curvature sensing circuit including a light sensitive device embedded in said plate surface immediately ahead of the needle hole for controlling the velocity of the wheel, and mechanism responsive to the heightwise motion of said feeding member for causing the wheel and the presser to engage the work with greater pressure while the needle is available to serve as pivot therefor.

18. A sewing machine as set forth in claim 17 and further characterized in that said circuit includes a biased power supply for determining a null line along which zero steering error occurs, and means for shifting the null line transversely of the direction of feeding.

19. In a machine of the type having a work support, a tool movable toward and from an operating zone on the support to engage successive portions of a work piece thereon, and means movable relatively to the support to advance the work piece in translation past the tool while it is inoperative thereon, the combination comprising guidance mechanism for exerting variable torque on the work piece at a single locality close to the surface of said support, said mechanism comprising a servo-controlled steering wheel the work-engaging perimeter of which is disposed adjacent to said surface and a presser cooperative with said perimeter, means for actuating the presser to ward the perimeter with greater pressure while the tool engages the work piece, said actuating means comprising a yieldingly pivotal lever for carrying said presser and having operative connection to said work advancing means, a curvature sensing circuit for continuously controlling the velocity of the steering wheel, said sensing circuit including a light sensitive device disposed closely adjacent to the operating zone and transversely of a null line, and a source of light disposed in the vicinity of said line and on the opposite side of the work piece from said device.

20. In a machine having a tool for operating on successive portions of sheet material of irregular curvature, mechanism for feeding the material in increments at the tool, work guidance mechanism including a light sensitive cell responsive to curvature of the material in a locality just ahead of the operating zone of the tool, a tubular main shaft for driving the tool, operating connections including eccentric means on the shaft and by which said feeding mechanism is driven, a collar rotatably attached to the main shaft and providing a pivot for said eccentric means, and a rod shiftable axially within the main shaft during operation of the machine to change the eccentricity of said eccentric means to modify the length of the feeding increments upon sharp change in said curvature approaching the cell.

21. In a sewing machine having stitch forming devices and means for feeding a work piece in translation intermittently past these devices, a partly tubular main shaft having operative connections, respectively, for driving said means and devices to insert a seam of normal stitch length, automatic guidance means responsive to edge curvature of the work piece in a locality immediately ahead of the devices for controlling steering of the work with respect thereto, said operative connections to the work feeding means including a strap eccentrically receiving the tubular portion of the main shaft, mechanism shiftable axially of the latter to modify the eccentricity of the strap, and control means operable as sharper edge curvature approaches the device for thus shifting the mechanism to change the stitch length from normal during negotiation of the sharper curvature and then back to normal without interrupting operation of the machine.

22. In a machine having a tool for operating on a flat work piece of irregular edge curvature, mechanism for feeding the work piece in translation with respect to the tool, electrical means including a light sensitive device responsive to rays directed past the work piece for steering the latter according to its curvature and in time relation to said feeding mechanism, and control means including a second light sensitive device located immediately ahead of the first-mentioned device for causing the steering means at a selected corner of the work to permit the feeding mechanism to move the work piece in a straight direction away from the tool.

23. In a machine having a tool adapted to operate along the margin of sheet material, means for feeding the material in translatory increments past the tool, mechanism for applying a steering torque at a single locality to guide the material with respect to the tool according to the curvature of said margin, and a control circuit including a light sensitive device arranged ahead of the tool and energizable upon being increasingly uncovered by a portion of the margin automatically to stop operation of the machine.

24. In a machine having a tool adapted to operate along the margin of sheet material, means for feeding the material in translatory increments past the tool, mechanism for applying a steering torque at a single locality to guide the material with respect to the tool according to the curvature of said margin, said mechanism including a curvature sensing circuit comprising a servomotor, a power amplifier connected to the motor, and a preamplifier from which sensing signals are normally transmitted to the power amplifier, and a control circuit energizable at the will of the operator to send an overriding command to the power amplifier whereby the servomotor abruptly causes the guidance mechanism to apply a torque for ejecting the material from the operating locality of the tool.

25. In a machine having a tool adapted to operate along the margin of sheet material, means for feeding the material in translatory increments past the tool,
mechanism for applying a steering torque at a single locality to guide the material with respect to the tool according to the curvature of said margin, said mechanism including a curvature sensing circuit comprising a servomotor, a power amplifier connected to the motor, and a preamplifier from which sensing signals are normally transmitted to the power amplifier, a control circuit including a light sensitive device disposed ahead of the tool and energizable upon being increasingly uncovered by a portion of the margin, and a second control circuit normally disconnected from the power amplifier and having an independent input, the arrangement being such that when said device is thus energized said second control circuit provides an input to the power amplifier in lieu of that from the preamplifier whereby said feeding means is permitted to feed the material in a substantially straight line away from the tool.

In a machine having a tool arranged to operate on or near the edge of a work piece, means for feeding the work piece rectilinearly an increment between successive operations of the tool, guidance mechanism including a wheel frictionally engageable with the work piece at a locality spaced from the operating path of the tool, mechanism for operating the guidance mechanism effectively only when the tool is in engagement with the work piece to serve as a center for its turning movement, and an electric curvature sensing means including a light responsive device for controlling the velocity of said wheel, and a servo motor-tachometer responsive to said device for continuously driving the wheel, said sensing means being adapted to detect change in curvature of said edge, and said device being spaced immediately ahead of the tool and close to the edge for supplying controlling power to said motor whereby the wheel velocity is continuously corrected in accordance with said curvature change.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Inventor(s)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,569,394</td>
<td>Ray</td>
<td>Jan. 12, 1926</td>
</tr>
<tr>
<td>2,259,502</td>
<td>Topham et al.</td>
<td>Oct. 21, 1941</td>
</tr>
<tr>
<td>2,483,138</td>
<td>Helmer</td>
<td>Sept. 27, 1949</td>
</tr>
<tr>
<td>2,742,005</td>
<td>Quinn</td>
<td>Apr. 17, 1956</td>
</tr>
<tr>
<td>2,863,407</td>
<td>George</td>
<td>Dec. 9, 1958</td>
</tr>
<tr>
<td>2,958,302</td>
<td>Frankel</td>
<td>Nov. 1, 1960</td>
</tr>
<tr>
<td>2,971,483</td>
<td>Cordier</td>
<td>Feb. 14, 1961</td>
</tr>
<tr>
<td>2,979,745</td>
<td>Schaefer et al.</td>
<td>Apr. 18, 1961</td>
</tr>
</tbody>
</table>