ELECTRICALLY OPERATED RECIPROCATING TOOL

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The present invention relates to a tool, and more particularly to an improved electrically operated portable tool of the type having a single power stroke.

Portable tools are widely used for many material working operations and it is important that such tools be compact and light enough for easy and convenient manipulation, while being powerful enough to perform the desired operation. It is desirable that such a tool be convenient to use in a variety of locations, and for this reason an electrically operated tool may be preferred. In many applications, a tool with a single power stroke is preferred because of its effectiveness and speed.

One tool which satisfies these diverse requirements is the tool disclosed and claimed in U.S. Patent No. 3,179,866 of Richard H. Doyle, LeRoy N. Herrman and Joseph S. Neber. The tool disclosed in that patent includes a working element having a magnetic portion disposed adjacent an operating winding. A control circuit is disposed in the tool housing and is effective to energize the operating winding during the first complete half cycle of the alternating current potential following actuation of a control circuit by a switch. Energization of the operating winding results in movement of the magnetic portion and working element through a power stroke.

Although the tool shown in the above mentioned patent is highly satisfactory for many material working operations, it would be desirable to provide an even more powerful single stroke tool, without increasing the size and weight of the tool to the point where its portability is impaired. One possibility would be to improve the efficiency of the tool by using an increased amount of magnetic material associated with the working element, but this would increase the weight and size of the tool. Another problem is that the electrical energy available to the tool is limited by the maximum current of 90 amperes, or so available in the 110-120 volt lines normally used commercially. The use of energy storage devices, such as capacitors, for providing more power is not feasible because the size of the conductors connected to the tool becomes too large for convenient portability.

In many fastener driving operations, a fastener is first sheared from a strip of fasteners, and then is driven, both the shearing and the driving being accomplished by a moving armature accelerated by the operating winding. The force required to shear the staple may be large. For example, approximately 50 pounds of force is required to shear a one and one-half inch, 16 gauge staple. Accordingly, it would be desirable to provide a compact portable tool in which ample momentum is imparted to the armature by acceleration of the armature before shearing the staple, without substantially increasing the overall armature stroke and tool size.

Accordingly, it is an object of the present invention to provide an improved electrically operated portable tool.

Another object is to provide an improved portable tool of the single stroke type which is compact in size but which is capable of delivering a large amount of power.

A further object is to provide a tool including an improved winding arrangement and an improved control circuit for increasing the power delivered in the power stroke of the tool.

Another object is to provide an improved electrically operated tool provided with a novel armature assembly for achieving an increased armature displacement or stroke without a substantial increase in the size of the tool, and without the necessity for increasing the displacement or stroke of the working element.

A further object is to provide an improved armature assembly in which the initial inertia to be overcome by the magnetic field produced by the winding is reduced.

Another object is to provide a tool in which the armature attains a sufficient velocity easily to shear a fastener, without increasing the size of the tool.

In accordance with these and many other objects and advantages of the invention, one embodiment of the invention comprises a fastener driving tool including a housing within which is arranged a winding structure and an armature assembly mounted for movement adjacent the winding structure. In order to increase the power or energy imparted to the armature assembly during a single stroke, the winding structure includes a pair of windings disposed along the path of movement of the armature assembly and the control circuit includes means for energizing the windings on succeeding half cycles of the alternating current source in a sequence corresponding to the direction of movement of the armature assembly. Thus the armature assembly is accelerated throughout a full cycle of the alternating current potential source, first by one winding and immediately thereafter by another winding, and powerful single stroke is achieved.

In accordance with a feature of the invention, the control circuit includes means for energizing the first winding during a first half cycle of the alternating current source, and means responsive to energization of the first winding for energizing the second winding during the immediately following half cycle. The control circuit includes a first controlled conduction device in series between the first winding and the potential source, and means for applying a control signal to the first controlled conduction device to energize the first winding during one half cycle. A second controlled conduction device is in series with the second winding and the source. A trigger circuit is provided for applying a control signal to the second controlled conduction device in response to energization of the first winding for energizing the second winding during the following half cycle.

The use of more than one winding to achieve a longer period of acceleration of the armature gives rise to a necessity for increased armature displacement, since a longer stroke must be used to take advantage of the full period of time during which the windings are energized. In accordance with a feature of the invention, there is provided a novel armature assembly capable of providing a long armature stroke while keeping the tool compact in size, and without the necessity for long driver blade stroke. Thus the armature assembly includes a working member, including a driver blade, and a magnetic member movable from a rest position to an operating position to drive the working member through a single power stroke. The magnetic member and the working member are coupled together for limited movement with respect to each other, so that upon energization of the winding the magnetic member moves a distance from the rest position before engaging and driving the working member. This construction also assures that the working engaging member has sufficient momentum to shear the fastener from a strip, and does not require a large housing for movement of the armature.

Many other objects and advantages of the invention will become apparent from considering the following detailed description in conjunction with the drawing, in which:

FIG. 1 is a partial sectional view through the head por-
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3. tion of a fastener driving tool embodying the present invention; FIG. 2 is a view similar to FIG. 1 illustrating the fastener driving tool at the end of a power stroke; and FIG. 3 is a circuit diagram of the control circuit of the tool.

Referring now to the drawing, there are illustrated some portions of an electrically operated fastener driving tool designated by the reference numeral 10. The fastener driving tool 10, preferably of the portable type, includes a housing 12 having a handle portion (not shown) and a vertically extending head portion 14 illustrated in section in FIGS. 1 and 2 of the drawing. Adjacent the lower end of the head portion 14 is disposed an electrical winding structure designated as a whole by the reference numeral 16. An armature assembly 18 is mounted for vertical reciprocating movement adjacent the winding structure 16, and includes a work engaging portion 20 and a magnetic portion 22 coupled to the work engaging portion 22. The tool 10 includes a control circuit generally designated as 24 and illustrated in FIG. 3 of the drawing. Preferably, the control circuit 24 may be contained in the handle of the tool 10. The control circuit 24 serves to energize the winding structure 16 in order to drive the armature assembly 18 downwardly through a single power stroke against a fastener 26 (FIG. 1).

In accordance with a feature of the invention, the electrically operated tool 10 delivers a large amount of power with each single stroke of the armature assembly 18. The winding structure 16 includes a pair of windings 28 and 30, and the control circuit 24 serves to energize the windings in sequence during consecutive half cycles of the alternating current supply voltage. As a result, the armature assembly 18 is accelerated throughout a full cycle of the alternating current potential source, and, as a result, approximately twice as much energy is imparted to the armature assembly as would be the case with a half cycle energization period.

Since the armature assembly is accelerated throughout an entire cycle of the alternating current potential source, the distance through which the armature moves, or the armature stroke, is greater than would be required in a half cycle arrangement. In order to keep the tool 10 compact in size for portable use, and to permit a short driver blade stroke, the work engaging portion 20 and the magnetic portion 22 of the armature assembly 18 are coupled for limited movement relative to each other. As a result, the magnetic portion 22 moves through part of its longer stroke before engaging and driving the work engaging portion through a shorter stroke.

Referring now more specifically to the construction of the tool 10, the two windings 28 and 30 are supported near the lower end of the head portion 14 of the tool on a two-section bobbin 32. The bobbin 32 includes an axially extending opening 34 in which the armature assembly slidingly reciprocates. The windings 28 and 30 are thus disposed through the path of movement of the armature assembly, with the winding 28 being disposed closer to the top of the head portion 14 than the winding 30.

Having reference now to FIG. 3 of the drawings, the control circuit 24 of the tool 10 is illustrated. The control circuit 24 is preferably formed on a suitable support and then encapsulated or "potted" in any of the well known compositions therefor. The circuit 24 may be mounted within the housing 12 of the tool 10, and preferably within the handle which can extend laterally from the illustrated head portion 14 in the manner illustrated in the above mentioned U.S. Patent No. 3,179,866.

The circuit 24 includes a pair of input terminals 36 and 38 adopted for connection to an alternating current potential source as by a flexible conductor, and also includes terminals connected to the windings 28 and 30. The circuit is operated by a trigger actuated or workpiece engaging switch so that when the switch is operated, the armature assembly is accelerated through a single power stroke. More specifically, after operation of the switch, the winding 28 is energized during the desired half cycle of the desired polarity occurring after operation of the switch. The winding 30 is operated during the immediately following half cycle by a trigger circuit 40 responsive to energization of the coil 28.

The control circuit 24 includes an operating circuit generally designated as 42 for energizing the winding 28 during the properly polarized half cycle following operation of the switch, the control circuit 24 includes a set of normally closed switch contacts 44a and a set of normally open switch contacts 44b. The opening circuit 42 may be of any suitable type, and may comprise a circuit similar in some respects to the control circuit shown in the pending application of Richard H. Doyle, LeRoy N. Hermann and Joseph S. Naber, Ser. No. 257,677, filed Feb. 11, 1963, which application is assigned to the same assignee as the present invention.

The operating circuit 42 includes a gated unidirectional controlled conduction device 46, such as a silicon controlled rectifier, having an anode connected to one terminal of the winding 28 and a cathode connected to the supply terminal 36. When a positive potential is supplied to the anode of the gated rectifier 46 and a trigger signal is applied to the control or gate electrode thereof, the winding 28 is directly connected across the supply terminals 36 and 38 to develop a magnetic field for actuating the armature assembly 18.

The gate electrode of the gated rectifier 46 is provided with an operating control signal under the control of a second controlled conduction device 48, such as a silicon controlled switch. The cathode of the switch 48 is connected to the supply terminal 36 through a resistance element 50 and is coupled to the control electrode of the gated rectifier 46 through a blocking diode 52. The anode of the switch 48 is connected to the pair of normally open contacts 44b of the operating switch. The operating switch is actuated to close the normally open contacts 44b and to open the normally closed contacts 44a when it is desired to operate the tool 10.

The normally closed contacts 44a connect an energy storing means or storage capacitor 54 to a charging circuit including a capacitor 56 that is shunted by a resistance element 58. Positive-going half cycles of the alternating current potential from the supply terminals 36 and 38 are continuously supplied through a diode 60 to charge the capacitors 54 and 56. When the tool 10 is to be operated, the contacts 44a are opened and the contacts 44b are closed and the gate of the storage capacitor 54 is disconnected from its charging circuit and is connected to the anode of the controlled switch 48 so as to provide an operating potential therefor. The energy stored in the capacitor 54 is used such as to maintain the controlled switch 48 in a conductive condition for a period of time no longer than a full cycle of the alternating current potential source.

In order to synchronize the periods of conduction of the controlled conduction devices 46 and 48 with the potential supplied by the source 14 so as to insure that the potential applied across the rectifier 46 is of a proper polarity, and to insure that the rectifier 46 is fired at the beginning of the half cycle, the control electrode of the silicon controlled switch 48 is connected to a differentiating network including a capacitor 62 and a pair of resistance elements 64 and 66. The positive-going alternations in the alternating current potential source provide positive-going pulses or spikes at the gate electrode of the silicon controlled switch 48.

These positive-going pulses are continuously applied to the switch 48 so long as the circuit 24 is connected to an alternating current potential source. However, the device 48 is normally not placed in a conductive condition due to the absence of an operating potential across the anode and cathode of the device. However, during the
first properly poled half cycle following the time at which the contacts 44b are closed, the positive-going pulse supplied to the control electrode of the switch 48 places this device in a condition of positive discharge so that the storage capacitor 54 is discharged through the resistance element 50. This provides a positive-going pulse that is forwarded through the diode 52 to the gate electrode of the silicon controlled rectifier 46. Since the trigger pulse for the device 46 occurs only during positive-going alternations in the potential applied through the supply terminals, the anode of the device 46 is also at a positive potential with respect to its cathode, and the trigger pulse supplied through the diode 52 places the silicon controlled rectifier 46 in a conductive condition to connect the winding 28 directly across the potential source 14 during the entire half cycle of the proper polarity.

In order to insure stable operation of the rectifier 46 and switch 48, the resistance element 64 is coupled between the gate electrodes of the devices 46 and 48. This resistance element provides a feedback signal from the device 46 to the device 48 in order to hold the device 48 in its conductive condition, thereby insuring that the enabling signal to the device 46 is maintained and that the capacitor 54 is fully discharged to prevent multiple firing of the tool 10.

Bias regulation is provided by means of a Zener diode 68 connected between the supply terminal 36 and the anode of the diode 46. This is in its conductive condition, thereby insuring that the enabling signal to the device 46 is maintained and that the capacitor 54 is fully discharged to prevent multiple firing of the tool 10.

In order to energize the winding 30 on the half cycle of alternating current potential source immediately following the energization of the winding 28, the trigger circuit 40 includes a diode 74 and a capacitor 76 connected in shunt with the winding 28. During the period of time in which the winding 28 is energized, the capacitor 76 becomes charged and a positive gate signal is applied through a resistance element 78 to a second gate unidirectional conduction device 80, such as a silicon controlled rectifier. The resistance 78 serves to limit the current flowing to the gate electrode and to prolong the gating signal. During the half cycle of the alternating current potential source immediately following energization of the winding 28, the controlled conduction device 80 is placed in a conductive condition by the gate signal supplied by the triggering circuit 40. Accordingly, for the duration of this half cycle the winding 30 is effectively connected across the input terminals 36 and 38.

Since the energy stored in the storage capacitor 54 is sufficient to maintain the controlled conduction device 48 in a conductive condition for no longer than one full cycle of the potential supplied to the circuit, and since the silicon controlled rectifier 46 is placed in a non-conductive condition as soon as the potential on its anode swings negative relative to its cathode, the windings 28 and 30 are energized only once in response to each actuation of the switch 24. When the switch is returned to its normal position, the contacts 44b open and the contacts 44a close. Thus, the storage capacitor is disconnected from the anode of the silicon controlled switch 48 and charged through its charging circuit. A high value resistance 82 is connected across the contacts of the switch 44 in order to keep the anode of the silicon controlled switch 48 from floating when the switch is in its illustrated normal condition.

From the above it can be seen that each time the tool 10 is returned to its normal position, the contacts 44a open and the contacts 44b close. Thus, the storage capacitor 54 is disconnected from the anode of the silicon controlled switch 48 and charged through its charging circuit. The value of this resistance 82 is such that the storage capacitor 54 is discharged through the resistance elements 44a and 44b in order to carry the storage capacitor 54 across the position of the switch 44. When the switch is returned to its normal position, the contacts 44b open and the contacts 44a close. Thus, the storage capacitor 54 is charged through its charging circuit. The value of the resistance 82 is such that the storage capacitor 54 is discharged through the resistance elements 44a and 44b in order to carry the storage capacitor 54 across the position of the switch 44.
and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of this invention.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. An electric tool adapted to be energized by an alternating current potential source comprising a housing, winding means in said housing, an armature assembly mounted for movement adjacent the winding means, said winding means including a plurality of winding arranged along the path of movement of said armature assembly, and a control circuit for moving said armature assembly through a single power stroke and including means for energizing said windings on succeeding half cycles of the alternating current potential source and in a sequence corresponding to the direction of movement of said armature assembly in said power stroke.

2. An electric tool as claimed in claim 1 wherein said windings comprise first and second windings, and wherein said control circuit includes means for energizing the first winding, and includes means responsive to energization of the first winding for energizing the second winding immediately after energization of the first winding.

3. An electric tool as claimed in claim 2 wherein said control circuit comprises a first controlled conduction device adapted to be connected in series between the first winding and the potential source, means for applying a control signal to the first controlled conduction device to energize the first winding during one half cycle of the alternating current potential source, a second controlled conduction device adapted to be connected in series between the second winding and the potential source, and means responsive to energization of the first winding for applying a control signal to the second controlled conduction device to energize the second winding during the following half cycle of the alternating current potential source.

4. An electric tool as defined in claim 2 wherein said armature assembly includes a work engaging member, and a magnetic member movable from a rest position to an operating position during energization of said windings for driving said work engaging member through the power stroke, said magnetic member and said work engaging member being coupled for limited movement relative to each other so as to allow the magnetic member to move a distance from the rest position before driving the work engaging member.

5. An electric tool comprising a housing, winding means supported in said housing, a control circuit for energizing said winding means, and an armature assembly including a movably mounted work engaging member, and including a magnetic member movable from a rest position to an operating position for driving the work engaging member through a power stroke when said winding means is energized, said magnetic member and said work engaging member being coupled for limited movement relative to each other so as to allow the magnetic member to move a distance from the rest position before driving the work engaging member.

6. An electric tool as defined in claim 5 wherein said winding means includes an axial opening, said magnetic member being mounted for slidding movement through said opening upon energization of said winding means, and means defining a lost motion connection between said work engaging member and said magnetic member.

7. An electric tool as defined in claim 6 wherein said connection defining means includes a recess in said magnetic member, said work engaging member including a portion slidably received and held captive in said recess.

8. An electric tool as defined in claim 5 wherein said winding means includes a first winding disposed closest to the rest position of said magnetic member and a second winding disposed further from the rest position, and means for energizing said windings in sequence as said magnetic member moves from the rest to the operating position.

9. An electric tool as defined in claim 8 wherein said control circuit includes means for energizing said first winding, and means responsive to energization of said first winding for energizing said second winding.

10. In a portable electric fastener driving tool of the type adapted to be energized by an alternating current potential source and having an armature assembly movable through a single power stroke, the combination of first and second windings disposed along the path of movement of the armature assembly, means for energizing the first winding during a half cycle of the alternating current potential source, and means responsive to energization of the first winding for energizing the second winding during the immediately following half cycle of the alternating current potential source.

11. A control circuit for sequentially energizing a pair of loads by an undulating potential source comprising a first controlled conduction device adapted to be connected in series between the first load and the potential source, means for applying a control signal to the first controlled conduction device to energize the first load during an excursion of one polarity of the undulating potential source, a second controlled conduction device adapted to be connected in series between the second load and the potential source, and means responsive to energization of the first load for applying a control signal to the second controlled conduction device to energize the second load during an immediately subsequent excursion of a second polarity of the undulating potential source.

12. A control circuit as claimed in claim 11 wherein said second controlled conduction device includes output electrodes in series with said second load and includes a control electrode for establishing a conductive path between the output electrodes when a control signal is applied to the control electrode, and wherein said responsive means includes means in circuit with the first load for detecting energization of said first load, and means coupled between said detecting means and said control electrode for supplying a control signal to said control electrode after energization of said first load.

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