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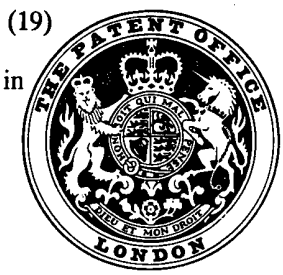
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(54) FORWARD/REVERSE SWITCHING DEVICE FOR FEEDER IN MACHINE TOOLS

(71) We, TOYOTA JIDOSHA KOGYO KABUSHIKI KAISHA, a Japanese corporation of 1, Toyotacho, Toyota, Aichi, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to a forward/reverse switching device for a feeder in a machine tool, and more particularly, to an improved directional switching device for a feeder in a machine tool driven by a direct current motor.

Generally, hydraulic cylinder type devices are employed for driving feeders to feed machine tool spindles, work-tables and the like to prescribed positions. The hydraulic cylinder device has several advantages such as its relative ease of control and great driving power which make it suitable as a thrust generator device in a feeder. However, its drawbacks include unstable feeder control as a result of temperature variations and the use of compressable fluids which affect productivity and durability of machine, in addition to such environmental problems as oil leaks and noise.

As opposed to the conventional hydraulic cylinder device, a electrical motor-driven feeder operation has been proposed. However, this method does not completely satisfy the benefits derived by the hydraulic cylinder operation in that, particularly with respect to an alternating current (AC) motor, simple changes in the rotational speed are difficult to achieve and this necessitates the installation of an expensive and complex gear box. Another drawback is the difficulty in securing and maintaining a prescribed stopping position of the feeder which causes inaccurate forward and backward feed movements, and mechanical friction and a shorter machine life.

As opposed to these drawbacks associated with the use of an AC motor, the direct current (DC) motor is more favourable although it, too, has the disadvantage of a complex circuit structure for switching the rotational direction, i.e., the direction in which the feeder moves. With the conventional DC motor, the DC current is supplied to the motor armature by a bridge circuit made up of four transistors. By switch-controlling the transistor bridge circuit, flow of the armature current is reversed thereby switching the rotational direction. Thus, the structure of the control circuit in the conventional DC motor device is not only more complex but also a protective circuit is necessary in order to control any abnormal excess voltage which is generated when the motor is stopped for reversing action. Because of this and other drawbacks, the DC motor has been employed only in special machine tools such as Numerically-Controlled (NC) machine tools which are equipped with expensive control devices.

An object of the present invention is to provide a directional, i.e. forward/reverse, switching device for a feeder in a machine tool utilising a direct current motor capable of accurately switching the direction of rotation by means of an exceedingly simple system.

According to the invention a forward/reverse switching device for controlling a feeder in a machine tool comprises;

a direct current motor for driving the feeder at a prescribed speed and with prescribed force;

a relay contact circuit connected in the armature circuit of said motor, and having an interlocking arrangement of two forward relay contacts and two reverse relay contacts; and

a sequence circuit for switch-controlling said relay contact circuit according to forward, reverse or stop commands, said sequ-

ence circuit comprising;

a plurality of auxiliary relays,

at least two main relays respectively controlling said forward relay contacts and said reverse relay contacts,

at least one timing relay,

at least two independently actuated contacts each controlling a corresponding one of said auxiliary relays, one of these contacts being actuated for forward 1 stop commands and the other thereof being actuated for reverse 1 stop commands, and

a plurality of relay contacts controlled by said auxiliary, main and timing relays, said plurality of relay contacts, auxiliary relays, main relays, timing relay(s) and independently actuated contacts being arranged and connected to control said relay contact circuit in a predetermined manner of operation when said forward, reverse and stop commands are given and so that when said main relays act to open the armature circuit no current is being supplied to the motor armature.

The invention will now be described further by way of example with reference to the accompanying drawings in which:-

Figure 1 shows an outline of the circuitry in a preferred embodiment of the invention,

Figure 2 shows a sequence circuit for use with the circuitry of Figure 1, and

Figure 3 shows a timing chart relating to the sequence circuit of Figure 2.

Referring first to Figure 1, a DC motor 10 is coupled to a known feeder (not shown). The motor 10 moves the feeder at a prescribed speed and provides a desired driving force to the feeder. Direct current is supplied to the armature of motor 10 via a relay contact circuit 12 and a servo control circuit 14. Servo control circuit 14 contains an output transistor 16 whose collector-emitter is coupled in line with the armature circuit. Base driving current from a driving circuit 18 is supplied to the base of transistor 16 providing desired control signals to transistor 16 in response to load conditions and speed and power instructions. Transistor 16 control an intermittent flow of the armature current and thereby controls the amount of current supplied to motor 10 according to its duty ratio. An inductance 20 is inserted into the armature circuit to smooth out the intermittent flow of direct current from the servo control circuit to the relay contact circuit 12, through which it is supplied to motor 10. Driving circuit 18 is controlled by the output from a comparator 22 when control external signals are received. A tachometer generator 24 is directly coupled to the shaft of motor 10 and is placed adjacent to it for purposes of counting the rotation speed of motor 10 at all times. The count is supplied to servo control circuit 14 via relay contact circuit 26 which then intructs comparator 22 and others of the rotational speed of motor 10. Servo control circuit 14 also has an interlocking circuit 27 for shutting off the base current of transistor 16 so as to prevent unnecesary rotation of motor 10 when it is to stop. Relay contact circuit 12 contains two sets of interlocking contacts MS12 and MS13 and MS22 and MS23. Relay contact circuit 26, coupled to tachometer generator 24, also contains two sets of interlocking relay contacts CR33 and CR34 and CR63 and CR62. Interlocking circuit 27 includes "b" contacts CR12 and CR41 and "a" contacts CR73, the latter being coupled in parallel with the "b" contacts. A load resistor 28 is coupled to motor 10 via "a" contact MS32 to form a closed circuit for dynamic braking when motor 10 is to be stopped. The aforementioned relay contacts MS12 and MS13 and CR33 and CR34 within the relay contact circuits 12 and 26, respectively, are closed when a command is received to rotate motor 10 forward; contacts MS22 and MS23 and CR62 and CR63 are closed at a reverse command.

Figure 2 shows a sequence circuit whose function is to ensure the accurate forward and reverse switching of relay contact circuits 12 and 26 shown in Figure 1. In the sequence circuit, CR_1 to CR_9 denote auxiliary relays, MS_1 to MS_3 denote main relays, and TR_1 denotes a timing relay.

Figure 3 is a timing chart showing the functions of the sequence circuit of Figure 2. The funtions of the relay contact circuits of the present invention are described hereinbelow in conjunction with Figures 2 and 3.

Prior to the start of feeder movement, motor 10 is in a stationary state and relay CR_7 is ON. Thereupon interlocking circuit 27 shuts off the base current of transistor 16 so as to prevent any armature current flowing to motor 10. The "ON" status of contact CR_{74} also energises relay MS_3 which in turn through contact MS_{32} closes the dynamic braking circuit of motor 10. At time t_1 (Figure 3) a forward command from contact 30 (Figure 2) energises relay CR_1 to close contact CR_{13} which energises relay CR_2 which operates at time t_2. The resultant closing of relay contact CR_{21} energises relay CR_3 which operates at time t_3. Contact CR_{21} also energises relay MS_1 to operate at time t_4, slightly later than relay CR_3. This time delay is achieved by means of a delay circuit comprising a capacitor 32 and a resistor 34. Opening of contact CR_{31} causes relay CR_7 to drop out at time t_5, whereupon interlocking circuit 27 becomes inoperative so as to allow the base current of transistor 16 to flow. By the closing of contact CR_{32}, relay CR_8 is energised and contact CR_{83} is opened at time t_6, whereupon relay TR_1 cannot be energised even though contact

CR_{35} is closed. Relay MS_3 is deenergised by the opening of contact CR_{81} and drops out at time t_7. Thus, with the forward command, the base interlock as well as the dynamic braking are released, relay MS_1 is operated, which in turn closes contacts MS_{12} and MS_{13}, and "forward" current from servo-control circuit 14 is supplied to motor 10.

While motor 10 is rotating in the forward direction, a change-speed switching signal from a limit switch LS_1 causes relay CR_8 to drop out at time t_8, whereupon relay CR_7 is energised and operates at time t_9, and opening of contact CR_{71} causes relay MS_1 to drop out at time t_{10}. Closing of contact CR_{74} causes relay MS_3 to activate the dynamic braking action at time t_{11} after a time delay introduced by a delay circuit comprising a capacitor 36 and a resistor 38. Contact CR_{82} is closed at time t_8, but relay TR_1 is energised and operates only after a prescribed time delay at time t_{12} and relay CR_9 is energised and operates at time t_{13}. Relay TR_1 is deenergised by the opening of contact CR_{91}, while relay CR_9 is held in the operated state by "hold-in" contact CR_{94}. Opening of contact CR_{92} causes relays MS_3 and CR_7 to drop out at time t_{14} thereby releasing both the dynamic braking and transistor base interlock. Closing of contact CR_{71} causes relay MS_1 to again pull in at time t_{15} and thus the change of the forward speed is accomplished. The change-speed switching operation described in the embodiment provides a decrease in the forward speed.

As the forward command is cancelled and contact 30 is actuated, relay CR_1 drops out at time t_{16} followed by dropping out of relay CR_2 and relay CR_9 at time t_{17}. Closing of contact CR_{92} causes relay CR_7 to pull in, whereupon the base interlock is activated. A little later, relay MS_3 pulls in at time t_{18} and still later relay TR_1 pulls in at time t_{19}. Thus, the dynamic braking and interlocking functions are performed in the same manner as in the previously described change-speed switching operation.

Meanwhile, a reverse command actuates and closes contact 40, whereupon relay CR_4 pulls in at time t_{20} and contact CR_{42} closes to energise relay CR_5 which pulls in at time t_{21}. Closing of contact CR_{51} causes relay CR_6 to pull in at time t_{22}, whereupon the closed contact CR_{64} energises relay CR_8 which pulls in at time t_{23}, and opening of contacts CR_{83} and CR_{81} deenergises relays TR_1, CR_7, and MS_3 which accordingly drop out. This action releases the brake and transistor base interlock and motor 10 is in an unrestricted state. The above reverse preparations completed, MS_2 pulls in after a time delay provided by a delay circuit comprising a capacitor 42 and a resistor 44 at time t_{24}. Thereafter motor 10 commences its reverse rotation.

The feeder having completed the desired reverse movement and having returned to its standard position, reverse command contact 40 is opened and relay CR_4 drops out at time t_{25}. This causes contacts CR_{12} and CR_{41} of interlocking circuit 27 to close, thereby interlocking transistor 16. Thereafter, contacts CR_{51} and MS_{22} and MS_{23}, and CR_{64} are opened in succession at times t_{26} and t_{27}, respectively, to open the armature circuit. Opening of contact CR_{64} causes relay CR_8 also to drop out at time t_{28}, closing of contact CR_{81} energises relay CR_7 which pulls in at time t_{29}, and closing of contact CR_{74} energises relay MS_3 which pulls in at time t_{30}, thereby causing the feeder to stop and maintain its prescribed position.

As described above, the forward and backward controls, as well as the speed switching control of motor 10, are accomplished by the sequence circuit of Figure 2.

The terms "pulling in" and "dropping out" used in the foregoing description in reference to the various circuit relays are used in the normal sense as referring to the operation of the relays as a result of energisation and deenergisation thereof, respectively.

WHAT WE CLAIM IS:-

1. A forward/reverse switching device for controlling a feeder in a machine tool, comprising:

a direct current motor for driving the feeder at a prescribed speed and with prescribed force;

a relay contact circuit connected in the armature circuit of said motor, and having an interlocking arrangement of two forward relay contacts and two reverse relay contacts; and

a sequence circuit for switch-controlling said relay contact circuit according to forward, reverse or stop commands, said sequence circuit comprising;

a plurality of auxiliary relays,

at least two main relays respectively controlling said forward relay contacts and said reverse relay contacts,

at least one timing relay,

at least two independently actuated contacts each controlling a corresponding one of said auxiliary relays, one of these contacts being actuated for forward/stop commands and the other thereof being actuated for reverse/stop commands, and

a plurality of relay contacts controlled by said auxiliary, main and timing relays, said plurality of relay contacts, auxiliary relays, main relays, timing relay(s) and independently actuated contacts being arranged and connected to control said relay contact circuit in a predetermined manner of operation when said forward, reverse and stop

commands are given and so that when said main relays act to open the armature circuit no current is being supplied to the motor armature.

2. A forward/reverse switching device as claimed in Claim 1, in which armature current is supplied to said direct current motor via a servo-control circuit.

3. A forward/reverse switching device as claimed in Claim 2, in which said servo-control circuit comprises a transistor switching element for controlling the armature current in said motor, and an interlocking circuit for shutting off the gate current or base current of said switching element when there is no forward or reverse command.

4. A forward/reverse switching device as claimed in Claim 3 in which said interlocking circuit shuts off said gate current or said base current during a prescribed time upon a command to change the motor speed, even when a forward or reverse command is in effect.

5. A forward/reverse switching device for a feeder, in a machine tool, substantially as herein described with reference to and as illustrated in the accompanying drawings.

E. N. LEWIS & TAYLOR,
Chartered Patent Agents,
144 New Walk,
Leicester, LE1 7JA.

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1594365 COMPLETE SPECIFICATION
3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

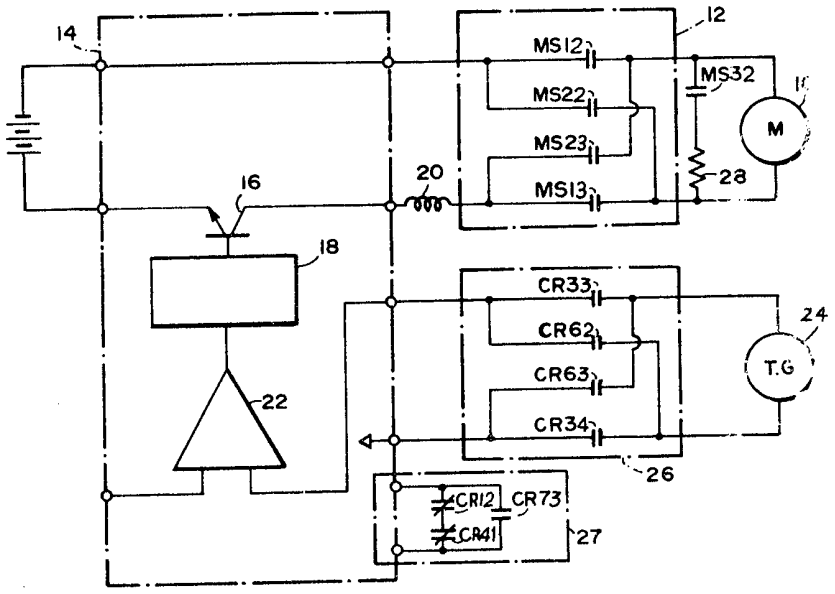


FIG. 1

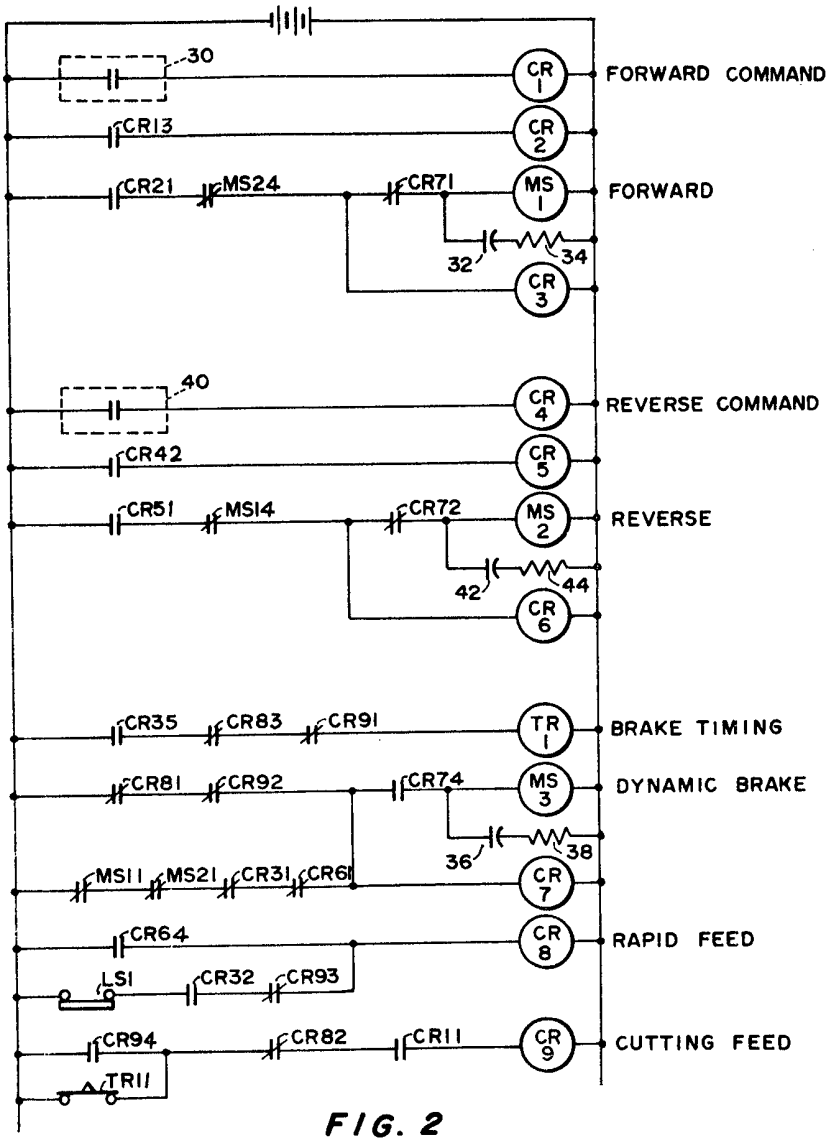

30
CR 1
FORWARD COMMAND
CR13
CR 2
CR21
MS24
CR71
MS 1
FORWARD
32
34
CR 3
40
CR 4
REVERSE COMMAND
CR42
CR 5
CR51
MS14
CR72
MS 2
REVERSE
42
44
CR 6
CR35
CR83
CR91
TR 1
BRAKE TIMING
CR81
CR92
CR74
MS 3
DYNAMIC BRAKE
36
38
MS11
MS21
CR31
CR61
CR 7
CR64
CR 8
RAPID FEED
LS1
CR32
CR93
CR94
CR82
CR11
CR 9
CUTTING FEED
TR11

FIG. 2

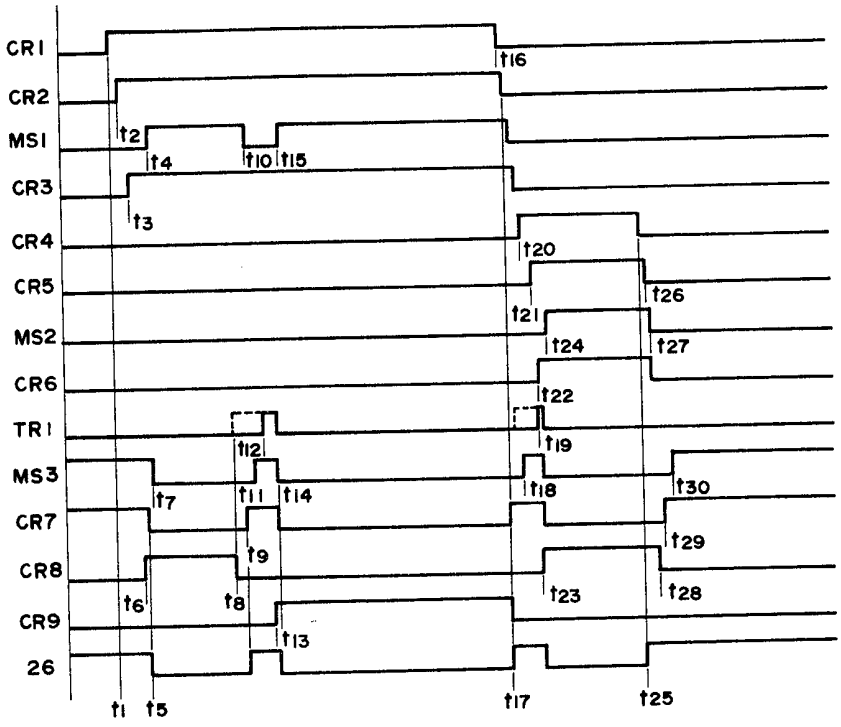

CR1
CR2
MS1
CR3
CR4
CR5
MS2
CR6
TR1
MS3
CR7
CR8
CR9
26
t1
t2
t3
t4
t5
t6
t7
t8
t9
t10
t11
t12
t13
t14
t15
t16
t17
t18
t19
t20
t21
t22
t23
t24
t25
t26
t27
t28
t29
t30

FIG. 3