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PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO SCREW FEEDS FOR MACHINE TOOLS

(71) We, TOYOTA JIDOSHA KOGYO KABUSHIKI KAISHA, a corporation organized under the laws of Japan 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 D.C. motor driven screw feed for the table of a machine tool.

D.C. motor driven screw type table feeds for machine tools are well known. Along with hydraulic means, these D.C. motor driven feed apparatus have superior characteristics as apparatus for controlling the feed of machine tools.

As shown in Figure 1, conventional feed driving motors cause a feed screw 3 to revolve via a coupling 6, but do not contain any thrust bearings which are able to bear a load. Instead, the load of the thrust which accompanies the linear motion of the slide 2 acts upon the feed screw 3 and is borne by the thrust bearings 5 installed in column 4 so that the load does not act upon the feed driving motor 1. Such conventional installation of thrust bearings 5 in column 4 has the following disadvantages: it increases the overall number of parts in the feed and it makes maintenance of the feed complicated and difficult.

In addition, conventional D.C. motor control apparatus with motor driven screw feeds which lack positional feedback have a particular drawback. This drawback is its inability to correspond well to the rate changing device. Specifically, although the rate of feed of the table is changed on account of a reduction in cycle time, during feed movement these apparatus have not been able to immediately cause the rate of revolution of the D.C. motor to conform to the rate ordered when an order to change the rate is sent to the D.C. motor. It is well known that the ability to respond is especially poor in cases where the inertia and weight of the table which includes the main shaft unit or work table are great. Accordingly, conventional rate changing orders for which conventional limit switches are employed have caused drawbacks such as table overdrive.

Furthermore, conventional motor driven feeds have an additional problem in that the feed screw collects dirt and requires lubrication and therefore must be provided with a protecting cover. Conventional methods for protecting the feed screws of machine tools, etc have consisted of protecting the feed screws indirectly by placing a cover over the entire feed slide mechanism, or covering the circumference of the feed screws with a helical spring type cover described in Japanese Patent No. 638,408. Such a helical spring type cover is commercially referred to as "elasticone".

In such configuration, however, the feed screw is not completely protected and no consideration whatever has been given to lubrication of the feed screw. Conventional protective covers in which consideration has also been given to lubrication of the feed screw are as shown in Figures 2 and 3. In these protective covers 7, the central axis of the cover 7 coincides with the central axis of the screw 8 so that a so-called grease pocket *7A* is formed by the space between the cover 7 and the feed screw 8. If grease, for example, is used as a lubricant for the feed screw 8, this grease is dispersed by centrifugal force as the feed screw 8 revolves. Accordingly, it is desirable that the volume of the grease pocket be small, as shown in Figure 2, in order to keep the grease stored inside the protective cover 7 in constant contact with the feed screw 8 so that sufficient lubrication action is obtained. On the other hand, however, when the volume of the grease pocket is small the heat capacity of the contained grease is small so that the grease is easily liquified. Since the absolute quantity of grease is small, it becomes necessary to frequently replenish the grease. Accordingly, a conflict arises since it is also desirable that the volume of the grease pocket is large, as shown in Figure 3. Thus, conventional protective covers for feed screws have suffered from a drawback in that in these covers it is difficult to adequately solve both the problem of centrifugal force acting upon the lubricant and the problem of heat capacity.

In accordance with the present invention there is provided a D.C. motor driven feed including a screw and nut for moving a table of a machine tool through a predetermined position in accordance with orders to determine the rate of feed, said motor driven feed comprising a braking circuit; and a control circuit for electrically coupling said braking circuit to said D.C. motor for a predetermined time responsively to an order to change the rate of feed; said control circuit and said braking circuit being arranged and configured such that when the braking circuit is electrically coupled to said motor by said control circuit, power to said motor is cut off and said motor is caused to act as a generator for converting rotational energy into electrical energy which is dissipated by the braking circuit.

In the drawings:—

Fig. 1 is a partial cross-sectional front view which illustrates a conventional feed device;

Fig. 2 is a cross-section which illustrates the relationship between a feed screw and a conventional protective cover;

Fig. 3 is a cross-section which illustrates the relationship between a feed screw and another conventionally protective cover;

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

Fig. 4 is a diagrammatic structural diagram of a D.C. motor driven feed in accordance with the present invention;

Fig. 5 is a diagram of a control circuit of the present invention;

Fig. 6 is a partial cross-section through the feed of Fig. 4;

Fig. 7 is a cross section taken along the lines 7-7 in Fig. 6 which illustrates the relationship between a feed screw and a protective cover of the feed of Fig. 1; and

Fig. 8 is a cross-sectional view illustrating the circulation of grease in the protective cover.

The feed control device shown in Figures 4 and 6 has supporting side plates 11 and 12 which are attached to a base 10 of the machine tool. A slide base 14 which supports a table 13 is coupled to both side plates 11 and 12. In this embodiment, a main shaft bed 15 is attached to table 13 and spindles 16 and 17 are provided so that they are free to rotate on the tip of main shaft bed 15.

A D.C. motor is coupled to supporting side plate 11 with the main shaft 19 of the motor 18 coupled to a feed screw 21 via a coupling 20. The feed screw 21 engages with a feed nut 22 fixed to table 13 such that rotation of the feed screw 21 moves the table to the left or the right as seen in Fig. 6 along the slide base 14, depending on the direction of rotation of the screw 21. A switch actuator 23 is attached to the table 13 and during traverse of the table 13 under the action of the feed screw 21 closes limit switches 24 as the actuator 23 and thus the table 13 passes through preselected positions on the slide base 14. Closing of the limit switches 24 which are provided adjacent to table 13 reduces the rate of feed of the table 13, i.e. the speed of the motor 18. The D.C. motor 18 is controlled by a D.C. motor driving circuit 25 and a braking circuit including a braking resistor 26 and contacts 27, 28 and 29, which are electrically coupled to the D.C. motor 18.

Figure 5 shows a control circuit which acts to electrically couple the braking circuit to the motor 18 on each occasion that one of the limit switches 24 is tripped to reduce the feed rate of the table 13. Since braking of the D.C. motor 18 is also necessary when the table 13 is to be stopped, a stop signal switch 30 and a reed relay 31 are connected in series. The stop signal switch 30 is not shown in Figure 4 but may be in the form of a conventional limit switch. The reed relay 31 controls the on-off condition of contacts 27, 28 and 29 shown in Figure 4, contact 27 being normally open while contacts 28 and 29 are normally closed.

The control circuit of Fig. 5 includes a switching circuit connected to the reed relay 31 in parallel with the stop signal switch 30. This switching circuit comprises a normal revolution signal contact 32, a rate change order limit switch 24 and a timer contact 33. The on-off condition of timer contact 33 is controlled by a timer relay 34 connected in series with the limit switch 24. The normal revolution signal contact 32 is closed during normal revolution when the table is fed from left to right as shown in Figure 4 and is open during reverse movement of the table so that the power damping switching circuit has no effect upon the operation of the

D.C. motor 18. The stop signal switch 30 is not triggered during traverse of the table 13 from right to left. Timer relay 34 switches contact 33 to the on condition for a presribed period of time after receiving an activating input signal. The period of time for which timer relay 34 is set is optional. In this embodiment, timer relay 34 is set for a period of time of approximately 0.1 seconds.

In operation, during normal feed of table 13, the reed relay 31 is in an unactivated condition so that the braking circuit has no effect upon the operation of the D.C. motor 18. Accordingly, the D.C. motor 18 revolves normally. When the table 13 reaches a selected position at which the feed rate is to be altered to a new reduced rate the actuator 23 trips, i.e. close a limit switch 24. As a result of this, the timer relay 34 in Figure 5 is supplied with an activating input signal via the normal revolution signal contact 32 and limit switch 24 such that contact 33 is closed for a prescribed period of time. Since the reed relay 31 is activated when the timer contact 33 is closed the contact 27 of Figure 4 is closed and the contacts 28 and 29 are opened, thus cutting off the input voltage to the D.C. motor 18.

Although the input voltage to the D.C. motor is cut off the motor 18 continues to drive the feed screw 21 for a short time thus generating a reverse electromotive force which causes current to flow through the braking resistor 26 generator a reverse torque which acts to cause rapid braking of the motor 18. Thus, in the present invention, the motor is made to act as a generator during braking. The mechanical energy of the rotating feed screw 21 and motor parts is converted into electrical energy and dissipated as heat in the braking resistor 26 to obtain a strong braking force acting on the motor 18 particularly when the D.C. motor 18 is revolving at a relatively high rate. Once the prescribed period of time for which the timer relay 34 has been set has elapsed the contact 33 opens, de-energising relay 31 which in turn closes switches 28 and 29 and opens switch 27. The braking circuit is thus isolated from the motor 18 which is then driven at the new, slower feed rate by the driving circuit 25.

Either a permanent magnet motor, a series wound D.C. motor with good braking characteristics or a double wound D.C. motor with series wound characteristics would be appropriate for use with the present invention. The latter motor is a type of compound D.C. motor which has a main series field winding and an auxiliary shunt field winding, and has characteristics of a series wound D.C. motor. In addition, the driving circuit 25 can be any well known circuit of the prior art for controlling D.C. motors.

In Figure 6, a permanent magnet motor 18 is shown coupled to the slide base 14 via side supporting plates 11 and 12. One end of the shaft 19 of the feed driving motor 18 is supported by double mounted thrust bearings 40 which are mounted in the casing 41 and restrained by a plate 42. The other end of shaft 19 is supported by a radial thrust bearing 43 which is provided in the rear of casing 41. A permanent magnet 44 is provided in casing 41 and a coil wound rotor 45 is coupled to shaft 19.

Furthermore, the shaft 19 is directly coupled to the feed screw 21 via a rigid coupling 20. The feed screw 21 engages with the feed nut 22 which slides along the slide base 14.

A protective cover 46 for feed screw 21 which is in the shape of a flanged cylinder open at one end and closed at the other end is coupled to one side of the nut 22. The protective cover 46 is coupled to the nut 22 by bolting the flanged end 47 of the protective cover 46 to nut 22. A gasket 48 is interposed between the flanged end 47 and the nut 22. Furthermore, as shown in Figure 7, the protective cover 46 is coupled to the nut 22 such that a small space 49 is formed between the bottom of the screw 21 and the bottom inside surface of the cover 46 and a large space 50 is formed between the top of the screw 21 and the upper inside surface of the cover 46. Therefore, a large grease pocket is formed in the space 50 and a small grease pocket is formed in the space 49.

In operation, the feed drive motor 18 causes the shaft 19 to revolve in accordance with signals from an external source. The revolution of shaft 19 is transmitted to the feed screw 21 via the coupling 20. Since the coupling 20 forms a rigid connection between the shaft 19 and the feed screw 21, the shaft 19 and the feed screw 21 may be considered to revolve as an integral unit without any play between the two. Furthermore, the revolution of the feed screw 21 is transmitted via engagement with the nut 22 to the table 13 so that the table is caused to slide along the slide base 14.

The load generated in the direction of the slide by the sliding motion of the table 13 acts as a thrust load upon the feed screw 21. This thrust load is transmitted without change via the coupling 20 to the shaft 19. The thrsut load acting on the shaft 19 is borne by the thrust bearings 40.

Furthermore it is also desirable that the thrust bearings 40 be also designed to bear radial loads along the thrust load. Accordingly, angular bearings or tapered roller bearings would be appropriate and in such instances the bearings would be able to bear a thrust load of two or three tons, which is the load capacity of the bearing.

As shown in Figure 8, when the feed screw 21 is caused to revolve by the driving motor not shown, in the figure, the grease is caused to adhere to the interior wall of the protective cover 46 by centrifugal force (as indicated by arrow A). Then, as a result of a reduction in viscosity due to generated heat, gravity causes the grease to move from the large space 50 in the upper portion to the smaller space 49 in the lower portion (as indicated by arrow B). This movement of grease causes the grease in the small space 49 to adhere to the feed screw 21. The grease adhering to the screw 21 is again dispersed by centrifugal force toward the interior wall of the protective cover 46 (as indicated by arrow C). Thus, the grease is circulated so that thorough lubricaion is accomplished.

Furthermore, it should be apparent that although the thrust bearing 40 is described as a double mount, a single self-catering roller bearing could also be used so long as it is able to withstand a substantial thrust load in both longitudinal and radial directions. In addition, since the coupling 20 forms a rigid connection between the shaft 19 and the feed screw 21, it would also be possible to combine the shaft 19 and feed screw 21 into a single unit thereby eliminating the coupling 20. Also, even though in the above description the protective cover 46 is cylindrical, a hollow part other than a cylinder could also be used providing (a) that it can contain a lubricant, (b) that the space between the protective cover 46 and the lower portion of the circumference of the feed screw 21 is small, (c) that the space between the cover 46 and the upper portion of the feed screw 21 is large and (d) that the grease can be moved by gravity.

As has been described above, a D.C. motor driven feed according to the present invention may have thrust bearings installed within the feed driving motor and a protective cover for the screw feed as well as means for improving the controllability of the D.C. motor.

The above described D.C. motor driven feed overcomes the difficulties of the prior art and provides the following advantages: (a) the rate changing response of the D.C. motor is improved, (b) a high precision feed control system is provided, (c) the feed may be less expensive than conventional feeds, (d) the feed may be easier to maintain and repair than conventional feeds, (e) the heat capacity of the lubricant in the protective cover is maintained at a high level, (f) the lubricant is kept in constant contact with the feed screw, (g) the feed screw is completely protected from its surrounding environment, and (h) adequate long-lasting lubrication of the feed screw is provided.

WHAT WE CLAIM IS:—

1. A D.C. motor driven feed including a screw and nut for moving a table of a machine tool through a predetermined position in accordance with orders to determine the rate of feed, said motor driven feed comprising a braking circuit; and a control circuit for electrically coupling said braking circuit to said D.C. motor for a predetermined time responsively to an order to change the rate of feed; said control circuit and said braking circuit being arranged and configured such that when the braking circuit is electrically coupled to said motor by said control circuit, power to said motor is cut off and said motor is caused to act as a generator for converting rotational energy into electrical energy which is dissipated by the braking circuit.

2. A D.C. motor driven feed as claimed in Claim 1 wherein said control circuit includes a timer for setting said predetermined time.

3. A D.C. motor driven feed as claimed in Claim 1 or 2 further comprising thrust bearings provided in said D.C. motor for bearing a thrust load acting in said feed screw.

4. A D.C. motor driven feed as claimed in Claim 1 or 2 further comprising a cylindrical protective cover coupled to said nut and covering said feed screw such that the bottom inside surface of said cover is in relative near proximity to the feed screw and the top inside surface of said cover is in relative far proximity to said feed screw.

5. A D.C. motor driven feed substantially as herein described with reference to Figs. 4 to 8 of the accompanying drawings.

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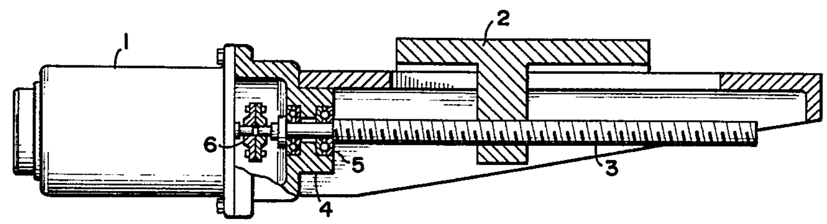

FIG. 1

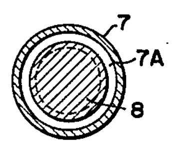

FIG. 2

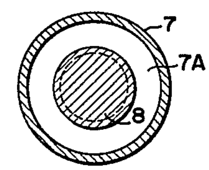

FIG. 3

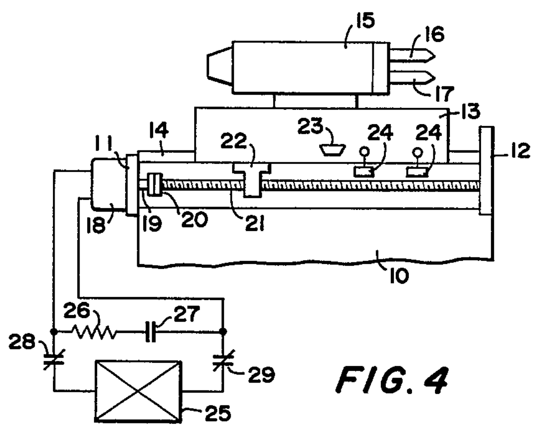

FIG. 4

1571322 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

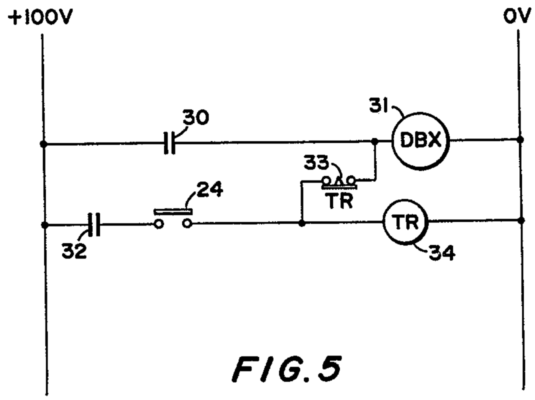

FIG. 5

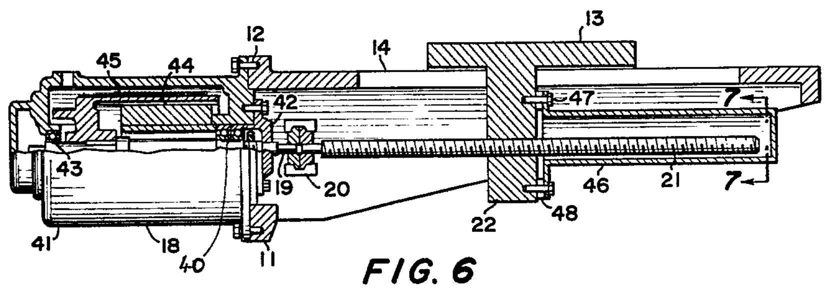

FIG. 6

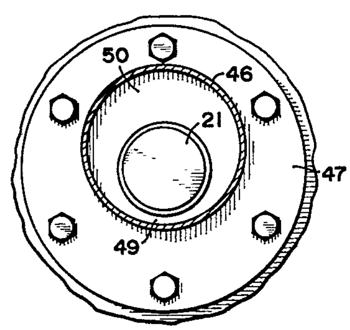

FIG. 7

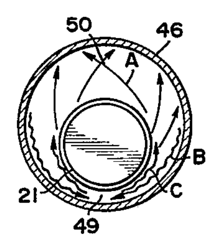

FIG. 8