

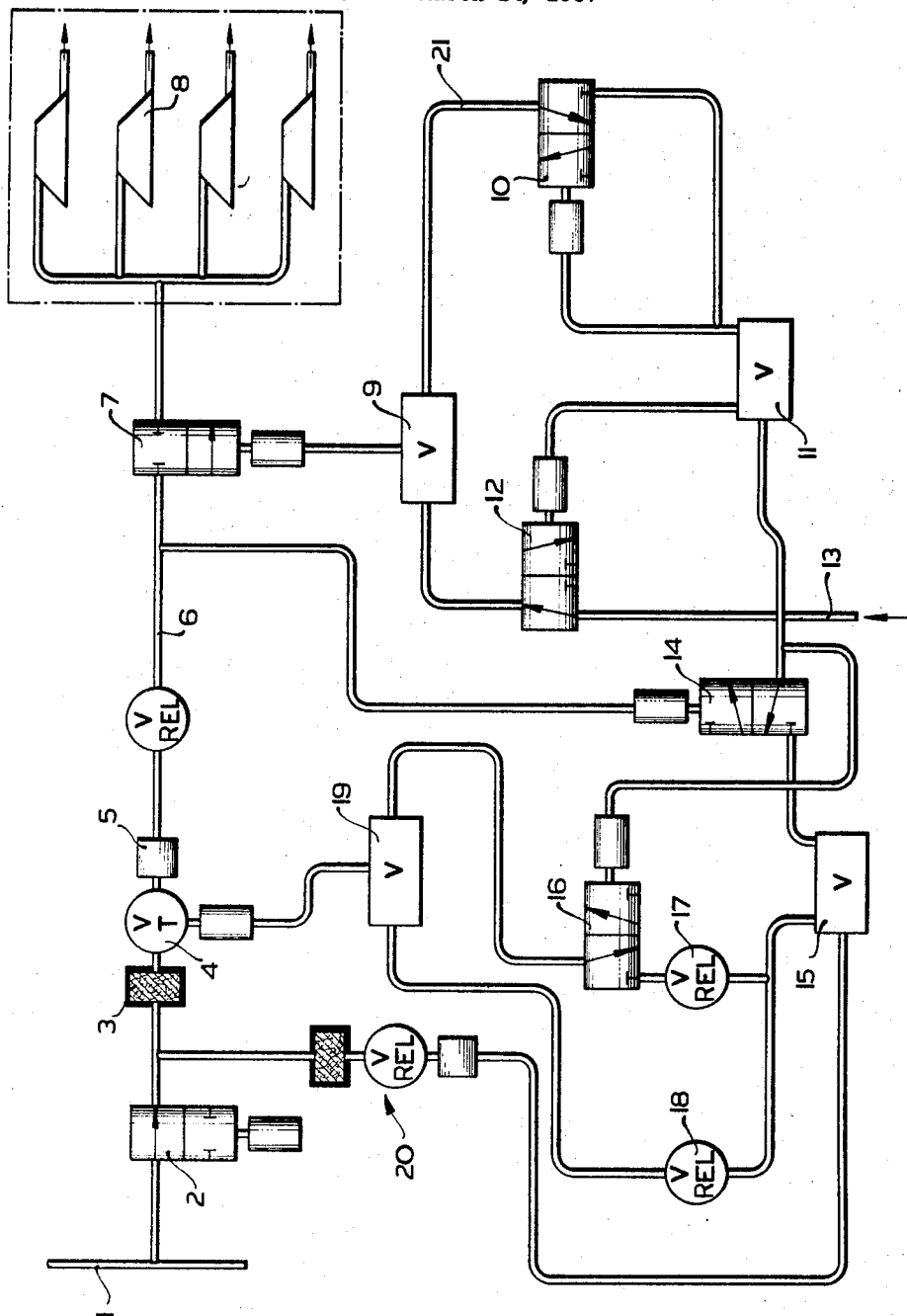
April 22, 1969

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3,439,754

APPARATUS FOR TIGHTENING SCREW CONNECTIONS TO A PRECISE TORQUE

Filed March 14, 1967



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APPARATUS FOR TIGHTENING SCREW CONNECTIONS TO A PRECISE TORQUE

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Filed Mar. 14, 1967, Ser. No. 622,967

Claims priority, application Germany, Mar. 16, 1966,

P 38,995

Int. Cl. B23q 5/00; F01b 25/04; B25b 21/00

U.S. Cl. 173—12

5 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus connectible as a unit between a source of operating pressure air and one or more pneumatically powered screw driving tools. The apparatus includes a first air flow circuit to allow operating air flow to the tools, having an initial pressure value to effect operation of the tools to run down the work to an initial degree of tightness. A second air flow circuit is automatically operable following attainment of the initial tightness of the work to increase the pressure value of the air flow to the tools to cause the tools to run the work down to a higher or final degree of tightness. A control circuit is included in the apparatus to effect operation of the second air flow circuit and to thereafter cause intermittent operation thereof until operation of the apparatus is finally shut off.

The invention concerns apparatus tightening of screw connections to a precise final tightening torque.

Such screw devices may be operated by compressed air, electrically or hydraulically. A box spanner to grip the head of the nut of the screw connection is placed on the operating spindle. Such screw connections are used singly or arranged in any desired number into so-called multiple screw implements.

In many applications of such screw devices it is important to tighten the screw connection within narrow tolerance limits to a quite definite required final tightening torque; as examples for such applications, the tightening of the cylinder head screws and of the driving rod connection screws of internal combustion engines can be listed.

There has been no lack of experiments to keep the final tightening torque achieved with such screw devices precisely constant with the aid of special devices. All these proposals either require comprehensive devices that make the screw device considerably more expensive and also heavier or the desired close tolerances of the final tightening torque, in the order of size of $\pm 5\%$ and less, cannot be achieved.

On the other hand, a mechanical screw device has become known by means of which the screw connection is first of all pre-tightened to a torque below the desired final tightening torque and then post-tightened automatically, after a certain interval of time, to the final tightening torque. In this way, significantly closer tolerances for the final tightening torque can already be achieved because hereby the screw connection is enabled to "settle down" for the last part of the tightening process. Such a settling down takes place in particular if together with the screw connection, elastic seals, spring washers etc. are also tightened; the same also applies to the tightening of expansion screws.

It has however now been found that especially with such particularly elastic screw connections and also when especially narrow torque tolerances are required, this pre-tightening and single post-tightening of the screw connection does not yet lead to the most favourable result obtainable. The aim of the invention therefore is the im-

provement of these known two-stage screwing methods and screwing devices in the sense of narrowing the tolerances of the final tightening torque without significant increase in the constructional means required for the control.

This problem is solved in accordance with the invention in that the post-tightening process is repeated automatically at least once. The improvement in the desired accuracy of the final tightening torque that can be achieved in this manner in comparison to the known tightening methods, divided into one pre-tightening and one post-tightening process, is somewhat surprising.

In many applications it can also be of great advantage, in a further modification of the invention, to carry out the pre-tightening in several stages in that several pre-tightening processes are carried out with a tightening torque that increases stepwise up to the final tightening torque. It is also of advantage that the power supply to the screw device is completely interrupted during a given, preferably adjustable, interval of time every time a higher tightening torque is switched.

The required or the most suitable number of repeats of the post-tightening process and possibly also of the pre-tightening process can be determined for each application by a series of torque measurements. In this, the procedure is to establish that number of repeats which, when exceeded, no longer shows an improvement in the tolerance.

The screw method in accordance with the invention has a particularly favourable effect on the tolerances of the final tightening torques especially when used on multiple screw units such as are very often employed in mass production in mechanical engineering. For, because of the repeated post-tightening, especially those screws are tightened up to the final tightening torque that, after the first post-tightening, still showed the lowest torque values. As a result, of course, the differences between the final tightening torques of all the screw connections tightened at the same time are considerably reduced since the screw connections tightened to the highest torque values already during the first post-tightening stage naturally can no longer be post-tightened to a still higher torque during all the post-tightening processes, with constant screw-driver setting, that is to say they do not experience any further change in the tightening torque during repeated post-tightening.

With pneumatically driven screw devices, it is of advantage in accordance with the invention to allow the control of the screw devices to operate also only pneumatically so that then no second power carrier, apart from compressed air, is necessary.

It is of particular advantage to design the control of the screw device as an independent unit which can thus be subsequently built into the power line of an existing conventional screw device. In this way, it is possible to adapt screw units already in use and still operating single-stage or only two-stage in the conventional manner to the method in accordance with the invention.

Other characteristics and advantages of the invention are indicated in the description following of the constructional example of the invention shown in the drawing. The drawing shows a pneumatic circuit of a screw device to carry out the method in accordance with the invention and especially of the fully pneumatic control of the device.

In the drawing, the compressed air system feeding the screw device is designated 1. The screw device, whose actual screw implements designated 8, are connected to the compressed air system by way of a main shut-off valve 2 which is generally operated by hand. The compressed air feed is effected by a filter 3, a finely controlled pressure reduction valve 4 and an oil cup 5. From here, a

main air line 6 leads via a main air valve 7 to the actual screw device which, in the example illustrated, consists of four pneumatically driven screwdrivers 8. 9 is a twin control valve for the interruption of the screwing operations during the individual switching over steps to higher tightening torques and for the final switching-off of the screw device. A special stage switching valve 10, a distributor 11 and a switching-off valve 12 for the pre-tensioning stage also serve the control in a type and manner to be further described below. 13 describes a control air line. A pressure control valve 14 is connected between the pressure reducing valve 4 and the main air valve 7 to the main air line 6. 15 is again a distributor, 16 a pressure switching valve. 17 and 18 describe two pressure controllers switched parallel to each other in the control line of the pressure reducing valve 4. 19 is again a twin control valve while 20 describes the maintenance unit, consisting of filter, fine pressure control and oil cup, for the entire control. The control line for the post-tightening stages leading from the stage switching valve 10 to the twin control valve 9 and causing switching-on and switching-off is described with 21.

The mode of action of the screw device in accordance with the invention, especially of its control, is as follows:

As shown diagrammatically, all the valves of the fully pneumatic control are also pneumatically controlled or operated because it is assumed that the screwdriver 8, indicated only diagrammatically, are to have a pneumatic drive. The same functions, as described below, can however also be carried out electrically or hydraulically or as combination of the various possible power carriers.

In order to initiate a complete tightening process, control air is passed into the control line 13 by way of a three-way valve (not illustrated) which may be operated by hand, mechanically, electrically etc.; as a result, a main valve 7 is opened through the twin control valve 9 so that the screwdrivers 8 are now driven with that pressure that corresponds to the desired pre-tightening torque. As a result, the screw connections are pre-tightened. Now, when all the screwdrivers have stopped because they have reached the pre-tightening torque, the stationary operating pressure which, as is known, drops when the screwdrivers are operating, again builds up in the main air supply line 6 to the main air valve 7 and switches the pressure control valve 14 to "open passage." As a result, the switching-off valve 12 is closed through the air distributor 11 and screwdrivers 8 are switched off via the twin control valve 9 as well as the main valve 7. Whilst in the pre-tightening stage the main air pressure control valve 4 is set to a lower operating pressure corresponding to the pre-tightening torque via pressure controller 18 and the twin control valve 19, it is set for the higher operating pressure corresponding to the required final tightening torque by way of the pressure switching valve 16, the pressure controller 17 and the twin control valve 19, after response by the pressure control valve 14. Retarded by a small interval of time, in order to ensure the full torque build-up up to main air valve 7 before the screwdrivers are switched on for tightening in the post-tightening stage, the special control valve 10 switches the screwdrivers on for the first post-tightening process by way of twin control valve 9 and main valve 7. After an adjustable opening time, the special valve 10 automatically switches to "closed" whereby the control line 21 is released so that the main valve 7 is closed via the twin control valve 9 and the screwdrivers 8 are switched off as a result. Again retarded by an adjustable interval, special valve 10 opens once more and thus initiates, as already described further above, the second post-tightening process after which it again releases the control line 21. This process of opening and closing of the special control valve 10 is repeated until, as a result of the release of the main control line 13 by means of the three-way valve (not illustrated) provided in it, the entire screwing process is completed. The number of post-

tightening processes is in this case determined over a period of time which in general leads to results that satisfy the required demands.

In certain applications however the attainable minimum tolerance of the final tightening torque depends upon whether a definite number of post-tightening states is maintained since both one post-tightening stage less and also one post-tightening stage more can already result in a significant change in the result. For these cases, a counter is arranged in the control line 21 which, after a pre-selectable number of post-tightening stages, automatically completes the tightening process. Another advantage of this design is that the setting of all the time retarding functions does not then require any particular care since it is necessary only to observe the proper switching sequence and adjustment of the total screwing time or of the total time of the sum of the post-tightening processes is no longer necessary and the most favourable number of post-tightening stages established is maintained in each case.

It may be of further advantage, to achieve the minimum tolerance of the final tightening torque in certain applications, to start with a small pre-tightening torque and to increase the pre-tightening torque stepwise to the nominal torque and then possibly additionally to repeat, once or several times, the final tightening process. This possibility too can be realised with the control circuit shown as example in that a number, corresponding to the number of pre-tightening stages, of pressure controller 17 and pressure switching valve 16 with delayed response moments is provided and the opening and closing of the special control valve 10 is adjusted in its intervals to the pre-tightening stages. Independently of the tightening of screw connections to a final tightening torque, to be maintained as accurately as possible, it is required in certain screwing cases that the screw elements are screwed in for a given length. In these cases, very precise observation of the specified screwing distance with very small tolerance is required and it is a further advantage of the method in accordance with the invention that in such screwing cases, too, significantly better results can be achieved than with the conventional methods, based solely on scanning of the screwing distance, because the screwing elements to be screwed in are turned further, in the area of their specified nominal position, only stepwise by small distances corresponding to the adjustment of the post-tightening stage switching device with the result that the accuracy of the switching-off, after attainment of the nominal screwing distance, is significantly improved because the tolerance can practically be only maximally equal to the measure of the step distance regulable in the manner previously mentioned.

The method in accordance with the invention and the screwing devices proposed for its realisation have proved of advantage also in conjunction with screwing units employed for the loosening of screw connections, especially multiple rotary impact screwdrivers with compressed air drive. For it has been found that in the conventional use of such screw units, especially with fully automatically operating machines, really tight screw connections are not loosened now and again. With screwing units with compressed air drive, the air consumption of the individual screwdrivers automatically increases very considerably if they are idling, that is to say if they have already loosened the screws appropriate to them. This means in the case of multiple compressed air impact screwdriver units that if, for example, in nine out of ten screws to be loosened in a screw arrangement have already been loosened, the air consumption of the screw unit is significantly higher than if all the screws are still fixed and the screwdrivers are operating under load. As is already known, this results in a significantly higher pressure reduction in the main air feed line to the screwdriver so that that impact screwdriver that is to loosen the last screw, which is the tightest, is subjected only to the smallest operating pressure; since

however the performance of the screwdriver is proportional to the operating pressure, this provides only a significantly reduced loosening torque so that then naturally it can no longer loosen the screw appropriate to it. This fault is overcome in the multi-stage methods in accordance with the invention in that the multiple impact screwdriver unit is switched on and off in regulable intervals when the switching-off time is always so adjusted that the stationary operating pressure prior to switching-on, has again built up fully. As a result, every individual screwdriver, but especially any that has not yet released the screw appropriate to it, is started in the course of the total screwing process several times with the full maximum performance. As a result of this measure, practically all screws are released with certainty. This is of great importance especially because in modern production plant, the work pieces joined with one another by means of screw connections are frequently automatically separated from one another after loosening of the screw connections when a screw connection that has not yet been loosened may lead to the destruction of either one or both work pieces or of the separating device itself.

I claim:

1. Apparatus for controlling flow of pressure fluid to one or more power tools whereby the tools will be caused to operate in a predetermined intermittent manner comprising, a main air line (6) connecting the tools to a source (1) of pressure fluid, a main air valve (7) arranged in the main air line which main air valve is normally open under the influence of pressure fluid, a control air line (13) for delivery of pressure fluid to the main air valve to keep it in open condition, a normally open switching-off valve (12) arranged in the control air line, a pressure reduction valve (4) arranged in the main air line between the main air valve and the source of pressure fluid, said pressure reduction valve being settable to regulate fluid pressure value in the main air line, a pressure control valve (14) arranged to close the switching off valve when fluid pressure in the main air line reaches a predetermined value, means (16, 17) to reset the pressure reduction valve to change the fluid pressure value in the main air line when the switching-off valve is closed, and means (10) to reopen the main air valve when the pressure reduction valve has been reset.

2. Apparatus as set forth in claim 1, wherein the apparatus is a separable unit connectible between the source of pressure fluid (1) and the tools (8).

3. Apparatus as set forth in claim 1, wherein a pressure controller (18) is arranged to provide an initial setting of the reduction valve (4).

4. Apparatus as set forth in claim 1, wherein the means (16, 17) to reset the pressure reduction valve (4) comprises a second pressure controller (17), and a pressure switch valve (16) connecting the pressure controller with the reduction valve having a normally closed condition, the pressure switch valve (16) obtaining an open condition in response to operation of the pressure control valve (14) to close the switching-off valve (12).

5. Apparatus for controlling flow of pressure fluid to one or more power tools whereby the tools will be caused to operate in a predetermined intermittent manner comprising, a main air line (6) connecting the tools to a source of pressure fluid, a main air valve (7) arranged in the main air line which main air valve is normally open under the influence of pressure fluid, a control air line (13) for delivery of pressure fluid to the main air valve to keep it in open condition, a normally open switching-off valve (12) arranged in the control air line, a pressure reduction valve (4) arranged in the main air line between the main air valve and the source of pressure fluid, said pressure reduction valve being set in a first condition wherein pressure fluid in the main air line is at a first value, a pressure control valve (14) connected to the main air line and responsive to pressure increase in the main air line to a predetermined amount to effect closing of the switching-off valve, pressure controllers (17, 18) arranged in parallel circuits and adapted to regulate the pressure setting of the pressure reduction valve, a normally closed pressure switch valve (16) arranged in a pressure fluid circuit between one of the pressure controllers and the pressure reduction valve, said pressure switch valve (16) being open when the pressure control valve (14) effects closing of the switching-off valve, and a special stage switching valve (10) arranged to intermittently open the main air valve (7) when the switching-off valve is closed.

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U.S. Cl. X.R.

81—52.4; 137—37