

Electric Motor-Driven Device -
Actuating System and Method of Operation Thereof

The invention relates generally to an electric motor-driven device actuating system and to a method of operation thereof, and more specifically to an operating method for an electric motor-driven brake-actuating system, more
5 particularly for rail vehicles, wherein a controllable electric motor at least indirectly tensions a spring accumulator and retains it in the tensioned condition to keep a brake open, the electric motor being at most de-energized to initiate the braking stroke, whereafter the expanding
10 spring accumulator acts on tensile or compression means to close the brake by applying the brake shoes.

In prior art systems of the kind above specified, the problem of automatic slack adjustment of the brake shoes has been solved mechanically (see for example German Patent
15 Specification No. 25 12 786 and Swiss Patent Specification No. 612 134). Spring accumulators of the kind above specified are basically known from German Patent Specification No. 15 84 136.

It is an object of this invention to replace the
20 mechanical slack adjuster, which is liable to wear, expensive,

bulky and requires maintenance, by a wear-free electric slack adjuster which requires no maintenance. Another object of the invention is to produce highly sensitive steady slack adjustment, due to the absence of any mechanical adjusting impulses, while maintaining the brake pressure unaltered.

According to one aspect of the invention, there is provided a method of operating an electric-motor-driven device-actuating system, wherein controllable electric apparatus including an electric motor directly or indirectly tensions a spring accumulator and retains it in the tensioned condition to keep the device in an open condition, wherein on initial operation of the system at the beginning of a working stroke an electric current is connected to the electric motor to reduce the force of the spring accumulator which latter actuates the device and wherein, in accordance with wear of the device, the voltage applied to the electric motor is reduced from a maximum value with no wear to a minimum value with maximum wear, the voltage being measured and controlled in such a way that the highest resultant force of the spring accumulator as reduced by the electric motor remains substantially constant but controlled.

According to a second aspect of the invention, there is provided an electric-motor-driven device-actuating system for carrying out the method of the first aspect comprising a spring accumulator, an electric motor for tensioning the spring accumulator through a coupling and for acting through said coupling to apply a counter force to the device to be actuated during expansion of said spring accumulator which applies a resultant force to said device, and an electric control circuit including an adjustable device which is

automatically adjusted during said expansion of the accumulator to cause a voltage to be developed dependent on the amount of expansion and extent of wear of the device, which voltage is applied to the motor so that the counter
5 force developed by such motor reduces the said applied resultant force at least at the end of the working stroke to a predetermined force which is substantially constant independently of wear of the device to be actuated.

A preferred embodiment illustrating the operation and
10 construction of a system in accordance with the invention will now be explained in greater detail, with reference to the drawings, in which:-

Figure 1 is a cross section showing the construction of an electric-motor-driven brake-actuating system with its
15 main mechanical and electrical parts;

Figure 2 shows the force-path characteristic of a spring accumulator and the constant pressure brake stroke and release path along the characteristic as the brake shoes wear, in the manner which takes place in an electrically
20 controlled braking and release operation performed by the system of Figure 1; and

Figure 3 shows the practical assembly of the two potentiometers which are rotated by a rear free shaft end of the motor via a step-down transmission.

25 Figure 1 shows an electric motor 1, preferably a d.c. series-wound electric motor of, for example, 24 volts operating voltage. The shaft of the motor is connected to a ball-and-screwthread drive coupling 2, 3 comprising a screw-threaded spindle 2 and a nut 3. The nut 3 is accommodated
30 positively and non-rotatably in a spring _____

abutment disc 4 which is extended as a push-and-pull tube 7 carrying a lug 8 connected to a brake linkage (shown diagrammatically at 19 to a reduced scale), whose brake shoes 20 can act on a brake disc 21 (shown diagrammatically) mounted on a spindle 22. The push-and-pull tube 7 constitutes a tensile or compression means which is forced out of a casing 6 by a spring 23 abutting the disc 4. As against this, the motor 1 compresses the spring 23 via the ball-and-screwthread drive coupling 2, 3 and pulls the push-and-pull tube 7 back into the casing 6. The spring accumulator has the general reference 5.

In Figure 2 the spring travel $S=0$ designates the position of the spring accumulator 5 stressed to the maximum, corresponding to the starting position shown in Figure 1. In this position of the spring accumulator 5 the brake shoes 20 are released, the motor 1 is de-energized, and the solenoid brake 18 incorporated in the motor or attached to its shaft is energized and prevents the spring accumulator 5 from expanding, since the ball-and-screwthread drive coupling 2, 3 is prevented from rotating by the solenoid brake 18 acting on the motor 1.

Sliders 11 and 12 of two potentiometers 9 and 10, namely a first potentiometer 9 and a second potentiometer 10, are at this level, as shown in solid lines in Figure 1 for the starting position of new brake shoes 20. A

Wheatstone bridge formed by the two potentiometers 9 and 10 is balanced via the sliders, 11, 12. The voltage between feed box input terminals K_1 and K_2 is zero, and for this reason the motor 1 is switched off via a control system in the feed box 14, while the solenoid brake 18 is switched on. The brake 20 is released and the vehicle (not shown) is able to travel. To initiate a braking stroke, the feed box 14 receives an electric braking impulse via terminal K_3 , which lifts the solenoid brake 18 of the motor 1. The spring 23 then forces the spring abutment 4 and tube 7 outwards, since the ball-and-screwthread drive coupling 2, 3, and the rotor of the motor 1 is no longer prevented by the brake from rotating and does not impede the outward travel of the spring abutment 4 and tube 7 due to the frictionless nature of the ball-and-screwthread drive coupling.

The spring abutment 4 (Figure 1) entrains the slider 11 of the first potentiometer 9; the voltage E_B at the first potentiometer 9 is reduced proportionally to the travel of the spring abutment 4, equal to the braking stroke B_W .

The braking voltage E_B (Figure 1) is applied via a highly resistive resistor 16 to terminals K_5 , K_6 of an amplifier 15 of conventional construction. The resistor 16 has such a high resistance that in practice it does not

disturb the balancing of the bridge circuit 9, 10 of lower resistance.

From the output terminals K_7 , K_8 of the amplifier 15 the motor 1 has applied to it via the feed box 14 a direct voltage proportional to the voltage E_B and develops during the braking stroke $S = B_W$ of 10 mm (Figures 1 and 2) a torque which is converted via the ball-and-screwthread drive coupling 2, 3 into a force counteracting the force of the spring accumulator 5. As can be seen in 10 Figure 2, therefore, the force acting outwardly on the lug 8 is reduced from $P_O = 450$ daN by the voltage E_B , which drops at the first potentiometer 9 from, for example, 8 volts to 6 volts, to $P_E = 200$ daN.

For the better understanding of Figure 2 it must be 15 stated that the left-hand P ordinate and the right-hand E_B ordinate are correlated:

i.e. $P_E = 200$ daN below P_1 is achieved by $E_B = 6$ volts, .

$P_E = 200$ daN below P_{n+1} is achieved by $E_B = 2.2$ volts and

20 $P_E = 200$ daN below P_{E-1} is achieved by $E_B = 1$ volt.

Accordingly, the acceleration and retarding values for the brake stroke remain constant over practically the whole usable travel of the spring accumulator 5; this is a very important feature.

25 Since Figure 2 contains no time scale, it should be

pointed out, as will also be explained in detail herein-
below, that the decrease from P_0 to P_E or P_n to P_E or
 $P_{E-1} - P_E$ must not extend linearly with the braking
stroke B_W in time. Figure 2 merely shows the decrease
5 in braking force to the closure pressure P_E after the
completion of the braking stroke. The same observation
applies for the change from P_1 to P_0 or P_{n+1} to P_n or
 P_E to $P_E - 1$.

The torque of the motor 1 controlled by E_B also
10 has a favourable influence on the speed of the braking
stroke - i.e. the spring accumulator 5 does not operate
abruptly, but moves at a controlled speed, i.e. as a
rule softly, into the braking position. By suitable
construction of the circuit of the amplifier 15 the speed
15 can be adapted to any requirement, for example, to suit
differing waggon weights.

The amplifier 15 has an additional monitoring member,
for example, a speed monitoring and switching-off system
as disclosed in German Patent Specification No. 22 09 001,
20 which switches off the voltage E_B after completion of the
braking stroke - i.e., after the brake shoes 20 have been
applied with 200 daN and the vehicle has stopped. The
motor 1 is then de-energized; its associated solenoid
brake 18 also remains de-energized - i.e. unapplied. As
25 a result, when the vehicle is stationary with the brake

applied, the higher braking force P_1 or P_{n+1} (Figure 2) becomes operative.

If the brake is to be released, the feed box 14 receives via the terminal K_4 the impulse 'lift', as a result of which the motor 1 receives its full operational voltage of 24 volts and moves the spring abutment 4 and tube 7 back into its starting position, i.e. from P_1 to P_0 or from P_{n+1} to P_n (Figure 2). On completion of this stroke, the two potentiometers 9 and 10 (Figure 1) are then again balanced; the motor 1 is therefore switched off by the control system in the feed box 14 and the solenoid brake 18 is switched on. The vehicle is then again free to travel.

Another possibility which should be mentioned is that by means of suitable control impulses it is possible to alter the braking force at choice between $P_E = 200 \text{ daN}$ and P_1 (Figure 2) with the brake shoes 2 on or applied, by controlling the voltage E_B applied to the motor 1 between 6 and 8 volts. This means that the spring accumulator brake according to the invention can be used not only as a safety and blocking brake, but at the same time also as a control and emergency brake. In view of the operation explained hereinbefore, it is easy to understand the automatic brake shoe slack adjustment: in correspondence with wear, the slider 11 of the first

potentiometer 9 moves lower and via the entraining member 13 entrains the slider 12 of the second potentiometer 10 by the same distance. When the brake is released, the Wheatstone bridge is then balanced more quickly by that amount of wear - i.e. the spring abutment 4 stops earlier.

For clarification, Figure 2 shows a central position $P_n: P_{n+1}$ and the end position $P_E: P_{E-1}$ in which the brake shoes 20 must be renewed and the second potentiometer 10 readjusted to the P_0 position. Figure 1 shows in chain lines only the position P_1, P_{n+1} and P_E , with the associated positions of the sliders 11 and 12.

During the life of the brake shoes, therefore, the braking stroke B_W is displaced on the spindle 2, which means that the motor 1 must produce its maximum power with new brake shoes 10, whereafter such power steadily declines.

In another advantageous variant of the invention, only a fixed resistor is used instead of the second potentiometer 10. The slider 12 and entraining member 13 are eliminated. The slider 11 then forms a Wheatstone bridge with a fixed opposite bridge point, which bridge is balanced only when the spring abutment 4 moves back into its top position P_0 . This means that, while all the other required open and closed loop control operations are

retained, the full spring travel S (Figures 1 and 2) is covered with a constant operating force P_E , although the force of the spring declines from P_O to P_E .

This feature enables the arrangement according to the invention to be used with the spring accumulator 5 for the closure and opening of doors and gates if a constant low closing pressure is required in order, for example, not to injure persons or parts of the body which are liable to be jammed in the doors or gates.

10 The capacity of resolution of the potentiometers 9 and 10, (Figure 3), in combination with the constancy of the amplifier 15, determines the sensitivity of response to brake shoe wear. Tests have shown that the sensitivity of response meets practical demands with the use of
15 commercially available parts.

Another advantageous use to which the invention can be applied is enabled by retaining the second potentiometer 10, but eliminating the entraining member 13, so that the second potentiometer 10 can be disposed in a
20 spatially distant feed box. With the position of the slider 12 controlled to vary at choice, the travel B_W would be alterable, and a manipulator or gripper can be opened to varying extents and nevertheless always apply the same force, also determinable by E_B .

25 It is also possible to use a non-linear first

potentiometer 9 to alter the force non-linearly through a non-linear alteration of E_B .

For the sake of completeness, it should also be pointed out that instead of the potentiometers 9 and 10, 5 electronic position-indicating means with a conventional output signal range of, for example, 0-20 mA, can be used if the control system of the manipulator system already processes these signals.

Finally, it should also be mentioned that a step- 10 down transmission 17 can be incorporated in the transmission between a shaft portion driving the slider 11 (Figure 3) and a rear shaft end of the motor 1.

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Claims

1. A method of operating an electric-motor-driven device-actuating system, wherein controllable electric apparatus
5 including an electric motor directly or indirectly tensions a spring accumulator and retains it in the tensioned condition to keep the device in an open condition, wherein on initial operation of the system at the beginning of a working stroke an electric current is connected to the
10 electric motor to reduce the force of the spring accumulator which latter actuates the device and wherein, in accordance with wear of the device, the voltage applied to the electric motor is reduced from a maximum value with no wear to a minimum value with maximum wear, the voltage being measured
15 and controlled in such a way that the highest resultant force of the spring accumulator as reduced by the electric motor remains substantially constant but controlled.
2. An operating method according to claim 1 wherein the said resultant force of the spring accumulator at the end of
20 an actuating stroke is adjustable to required values by means of control signals to control means for the motor.
3. An operating method according to claim 1 or claim 2 wherein to achieve a greater spring accumulator force than, the said resultant substantially constant force, the elec-
25 tric motor is disconnected.
4. A method according to claim 1, claim 2 or claim 3, wherein the device is a brake having a linkage acted upon by expansion of the spring accumulator during a working stroke to apply brake shoes, and wherein a constant braking force
30 is always maintained when the brake shoes are being applied, independently of wear of the brake shoes.
5. A method according to claim 4 as appendant to claim 3 wherein the said greater force is achieved when a braked component is stationary as compared with the said substan-
35 tially constant force obtained when the braked component is



* C L N S *

still not yet stationary.

6. An electric-motor-driven device-actuating system for carrying out the method of claim 1, claim 2 or claim 3, comprising a spring accumulator, an electric motor for
5 tensioning the spring accumulator through a coupling and for acting through said coupling to apply a counter force to the device to be actuated during expansion of said spring accumulator which applies a resultant force to said device, and an electric control circuit including an adjustable device
10 which is automatically adjusted during said expansion of the accumulator to cause a voltage to be developed dependent on the amount of expansion and extent of wear of the device, which voltage is applied to the motor so that the counter force developed by such motor reduces the said applied
15 resultant force at least at the end of the working stroke to a predetermined force which is substantially constant independently of wear of the device to be actuated.

7. An electric-motor-driven brake-actuating system for carrying out the method according to claim 4, having a
20 spring accumulator brake cylinder and a controllable electric motor, by means of which, with the interposition of a transmission device, for example a screwthread/ball coupling device, the spring accumulator can be tensioned to retain the brake open and expand when the motor is de-energized,
25 thereby to act via tensile or compression means to close the brake by the application of its brake shoes, and wherein the torque of the motor can be controlled down to stoppage, the linear movement of the tensile or compression means, for example a push/pull tube associated with the screwthread/
30 ball coupling drive, being transmittable to a slider of a first potentiometer, the slider of the first potentiometer entraining via an entraining member the slider of a second potentiometer after a predetermined expansion of the spring accumulator has been exceeded, and the two potentiometers
35 together with their sliders forming a Wheatstone bridge



which when balanced delivers a signal, for switching-off of the motor and switching-on of a motor blocking brake.

8. A system according to claim 7, wherein the slider of the second potentiometer can be adjusted and controlled at will, the entraining member being omitted.

9. A system according to claim 8, wherein the second potentiometer is spatially separated from the first potentiometer and is preferably disposed in a brake-actuating control unit.

10. A system according to claim 7 or any claim appendant thereto, wherein the second potentiometer is replaced by a fixed resistor of the same size with a fixed connection point, the first potentiometer and the fixed resistor forming a Wheatstone bridge balanced between the first potentiometer slider and the fixed connecting point.

11. A system according to claim 7 or any claim appendant thereto, wherein the motor blocking brake is a solenoid brake which can be controlled in the opening direction by an electric operating signal, the motor having applied thereto, simultaneously or with delay, a voltage which at the start is equal to or lower than the normal operating voltage and is reducible as the brake stroke increases, such decrease in voltage being controllable linearly or in accordance with a non-linear function, for example, by means of the slider of the first potentiometer.

12. A method of operating an electric-motor-driven device-actuating system, in particular a rail vehicle brake, substantially as hereinbefore described with reference to the accompanying drawings.

13. An electric-motor-driven device-actuating system, in particular a rail vehicle brake, substantially as hereinbefore described with reference to the accompanying drawings.

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