United States Patent

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[33] **Great Britain**
[31] **17823/68**

[54] **APPARATUS FOR CONTROLLING THE TENSION IN FLEXIBLE MATERIAL BEING HELICALLY WRAPPED ABOUT AN ELONGATED CORE**
9 Claims, 4 Drawing Figs.

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[51] Int. Cl. B65h 81/08
[50] Field of Search 57/3, 10, 11, 12, 13, 14, 15, 19

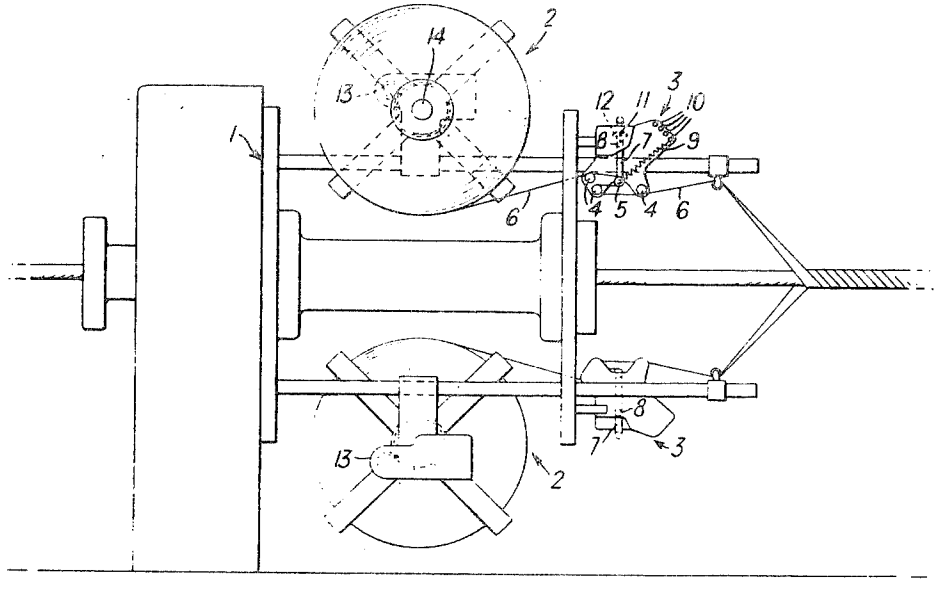
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3,233,397	2/1966	Bonikowski	57/13

Primary Examiner—John Petrakes
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ABSTRACT: The tension in elongated flexible material being drawn from a drum or over a capstan is controlled by an electromagnetically operated friction brake acting on the drum or capstan. The whole of the electrical power for operating the brake is obtained from a high-gain DC amplifier which has in its input circuit an impedance whose value is varied in accordance with the position of a sensing device which moves in accordance with changes in tension against a substantially constant biasing force. The system is stabilized to prevent hunting.



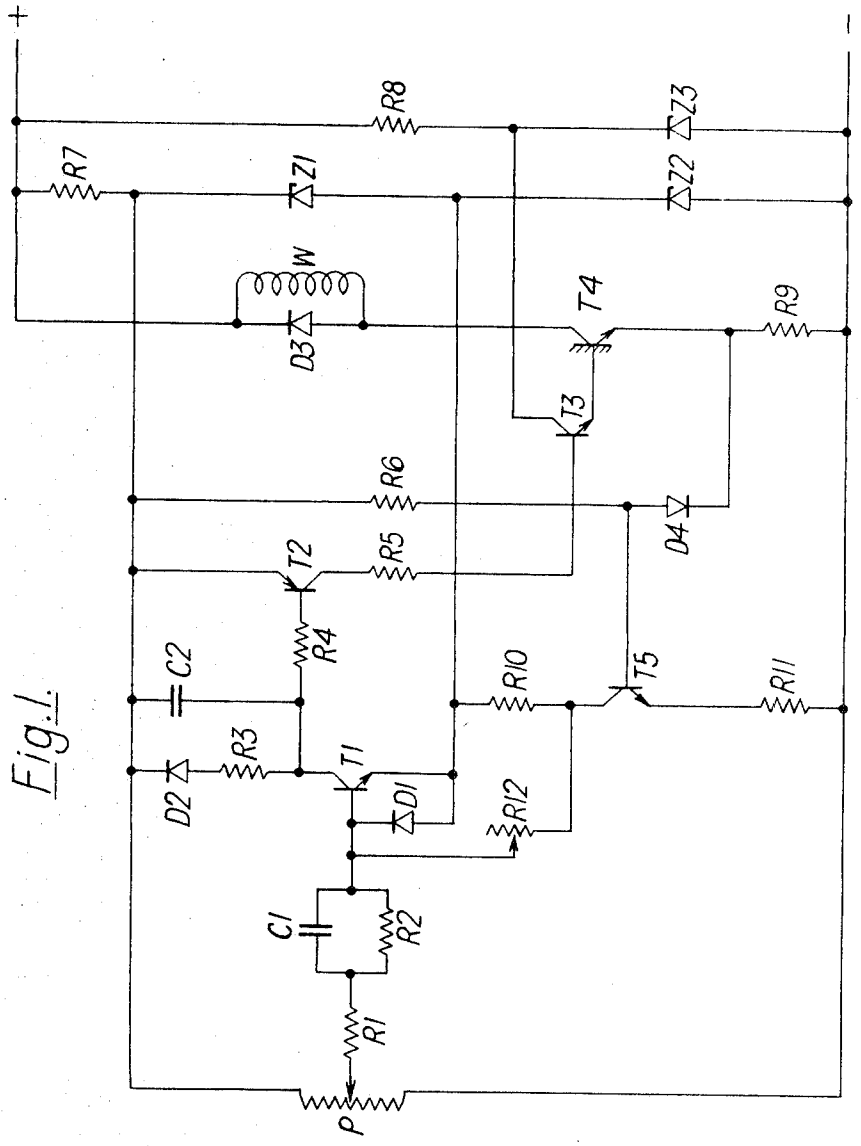
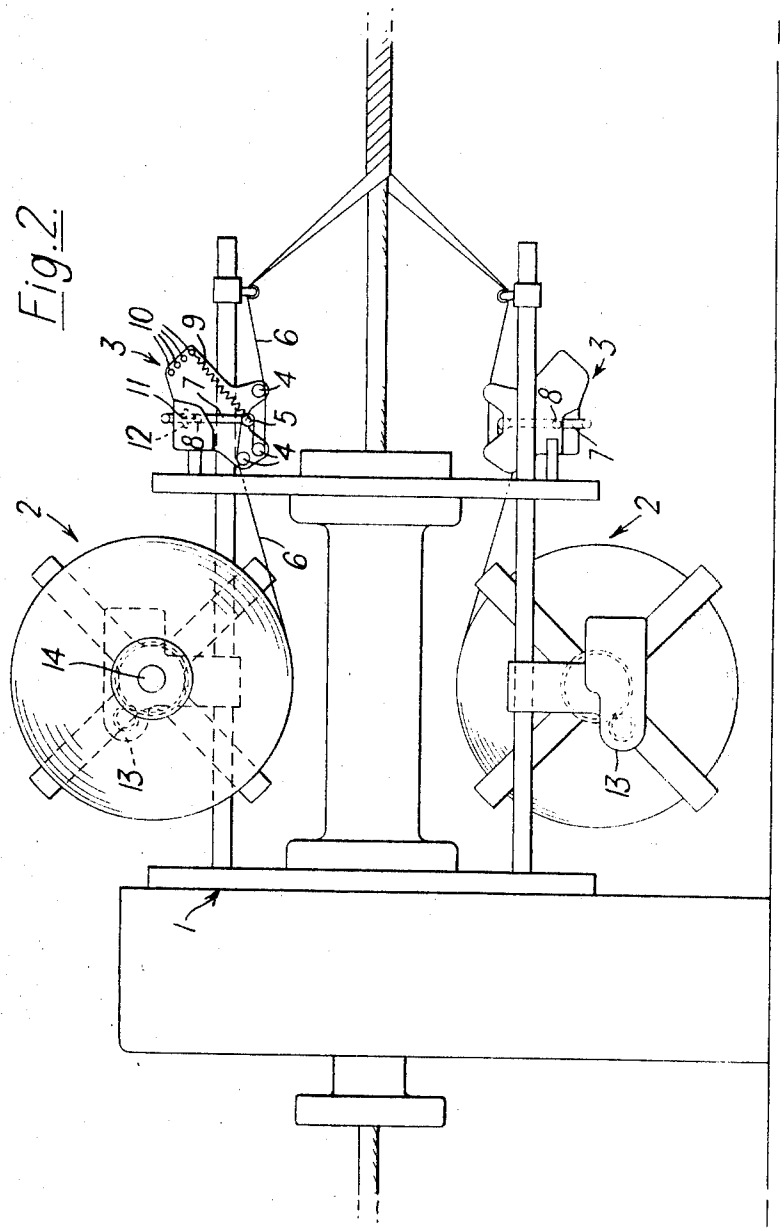


Fig. 1.

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Fig. 2



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Fig.3.

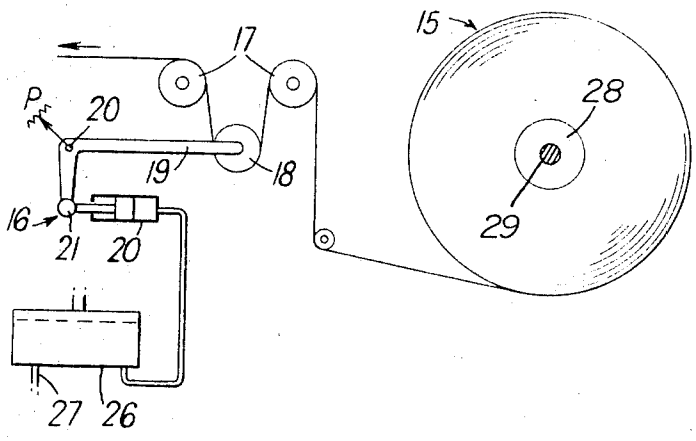
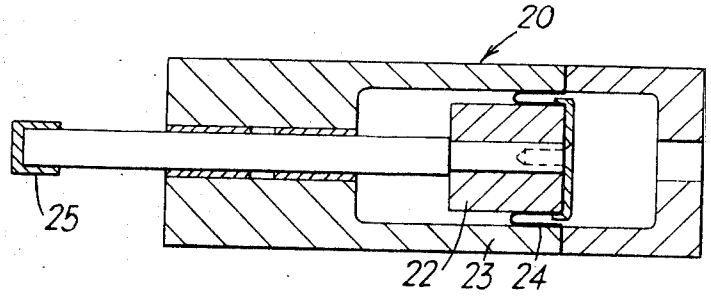


Fig.4.



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APPARATUS FOR CONTROLLING THE TENSION IN FLEXIBLE MATERIAL BEING HELICALLY WRAPPED ABOUT AN ELONGATED CORE

This invention relates to apparatus for controlling the tension in elongated flexible material, as it is being drawn from a braked supply drum or drawn over a braked capstan, by varying the braking torque applied to the drum or capstan. The invention is especially, but not exclusively, applicable to lapping heads for applying flexible material, for example tape, as a helical lapping to an elongated core passing axially through the lapping head; in such a head the supply drum, or each supply drum, may rotate bodily about the longitudinally advancing core or may be mounted coaxially with the core to rotate about the core axis.

One object of the invention is to provide tension control apparatus that is suitable for mounting on a lapping head, in that its sensitivity is not unduly affected by the speed of rotation of the head.

In the apparatus in accordance with the invention, a friction brake is used to brake the supply drum or capstan, the brake is electromagnetically operated, and the whole of the electrical power for operating the brake is derived from a high gain DC amplifier having in its input circuit a variable impedance, the value of which is varied in accordance with the position of a tension sensing device which moves in accordance with changes in tension in the flexible material against a substantially constant biasing force. The reference to the brake being electromagnetically operated includes the two alternative possibilities of using a force electromagnetically generated by the amplifier output as the braking force or using a constant braking force opposed by the varying force electromagnetically generated by the amplifier output. It is essential that the system should be stabilized by modifying the positional signal represented by the value of the variable impedance in the amplifier input circuit as is customary in negative feedback servomechanisms, by first and higher order functions of that value, so as to prevent hunting. For reasons of simplicity and efficiency we prefer to effect such stabilization by the use of a resistance-capacitance stabilization network in the amplifier input. The possibility of using an alternative stabilizing system, e.g. the use of a tachogenerator or generators to produce first and second order (velocity and acceleration) signals, is not however wholly excluded.

We prefer to use a multistage transistor amplifier with an overall feedback circuit directly connecting its output with its input.

The tension sensing device preferably incorporates a biased dancer roller around which the flexible material passes and suitable examples of such a device for use in accordance with the present invention are described in U.S. Pat. No. 3,233,397 issued Feb. 8, 1966 to Zbigniew Bonikowski. Instead of the spring biasing arrangements described in that specification, pneumatic biasing can be used; in the latter case when the tension in several flexible members is to be controlled simultaneously, individual pneumatic biasing devices for each dancer arm can be connected to a common reservoir, and the desired tension in all of the flexible members simultaneously adjusted by adjusting the gas pressure in the reservoir.

When the apparatus is used to control the tension in flexible material being helically applied by a lapping head to an elongated core moving relatively to the head along its axis of rotation, the dancer roller is preferably mounted on a pivoted arm that lies in a radial plane passing through that axis, with the pivot perpendicular to the plane, and a loop of the flexible material is passed over the roller in a direction such that the arm lies substantially perpendicular to the core axis when the tension is at its optimum value. The arm is preferably pivoted at a point between its ends and carries a counterbalance weight at one end and the dancer roller at the other end. The arrangement can be similar to that shown in FIGS. 11 to 15 of the above-mentioned patent to Bonikowski, with the reversible motor replaced by a friction brake and a double output high gain amplifier by a single output high gain amplifier.

The term "high gain amplifier" as used herein means an amplifier having a power output sufficient to provide the whole of the current required for operating the brake and yet having a low current input that can be controlled by a simple potentiometer or other variable impedance, that is to say, a potentiometer that can be actuated through the desired range under the action of a very small force exerted on it by changes in the tension in the flexible material. The power gain of the amplifier will normally be not less than 10^4 but is preferably greater than 10^5. The amplifier is preferably a transistor amplifier consisting of a number of successive transistor stages in cascade.

The invention will be more fully described, by way of example, with reference to the accompanying drawings wherein:

FIG. 1 is a circuit diagram of a preferred form of amplifier,

FIG. 2 shows a paper-lapping head, and

FIGS. 3 and 4 show apparatus for controlling tension in wires being drawn off from reels.

Referring to FIG. 1, the variable impedance coupled to the tension sensing device is a potentiometer P connected across a DC potential supply of 24 volts derived from a DC supply of 35 volts applied to the terminals marked + and −. The moving contact of the potentiometer P, which may for example be mounted on a dancer arm carrying a dancer roller around which the flexible material passes, is connected through a resistance-capacitance network R1, C1, R2 to the first transistor T1 of the amplifier. The input to the transistor T1 is protected by a diode D1 and the transistor is temperature stabilized by a resistor R3 and diode D2. The successive transistor stages of the amplifier are T2, T3 and T4; R4 and R5 being current limiting resistors. The output transistor T4 is mounted on a heat sink. A winding W of an electromagnetic brake controlling the tension in the flexible material is connected across a diode D3, which acts as a flyback diode to prevent over voltages when the current through the winding is switched off. Lower voltage supplies for the transistors and for the potentiometer P are derived from the single 35 volts supply to the amplifier through Zener diodes Z1, Z2 and Z3 and resistors R7 and R8.

The amplifier is stabilized by an overall feedback circuit, the feedback voltage being derived from a resistor R9 which limits the current in transistor T4. This feedback circuit includes a transistor T5, which is connected as an emitter-follower with collector load resistor R10, the emitter resistor being R11. Feedback is taken from the load resistor via a resistor R12, and the transistor T5 is biased by a diode D4 and a resistor R6 to cause it to work over a linear part of its characteristic. The amplifier is decoupled by a capacitor C2 to avoid oscillation.

The amplifier is designed to shut off when its input is below 12 volts and to have a linear output characteristic as the input from the potentiometer P rises from 12 volts to 24 volts. It will be appreciated that the characteristic of the circuit from the potentiometer P to the winding W will, under dynamic conditions, be varied by the resistance capacitance input network R1, C1 and R2.

FIG. 2 shows a lapping head equipped with tension control apparatus in accordance with the invention. The rotor bears a number of pad carriers 2 each associated with a tension monitor unit 3. The latter comprises fixed guide rolls and a dancer roll 5, the path of the paper 6 being apparent in the drawing. The dancer roll 5 is mounted on an arm 7 pivoted at 8 and biased by a spring 9 connected to one of several alternative pins 10 to give a preselected substantially constant force. Arm 7 carries a contact 11 running on a resistance track 12, these constituting the potentiometer P of FIG. 1. The output coil W constitutes the operating coil of an electromagnetic friction brake 13 which is geared to the spindle 14 of the pad carrier.

Assuming that the moving contact of the potentiometer travels from a position of zero output of the potentiometer P to its 24 volts maximum output whilst an arm carrying the sensing roller rotates through an angle of 50°, for the first 25°

of this movement the amplifier is shut off, for the next 10° its output (measured under "static" conditions) rises through zero to the value necessary to exert the maximum braking force, and during the remaining 15° of movement the output remains at a level above this value such that the braking force is kept at its maximum.

As already indicated, when the arm has rotated, under the action of increasing tension in the flexible material, through half (25°) of its normal span against a constant biasing force it is preferably substantially perpendicular to the axis of a core about which flexible material is being helically applied at controlled tension by a lapping head incorporating the tension control apparatus in accordance with the invention.

Although the arm is free to move through this whole range of 50° to absorb transient velocity fluctuations, its movement will normally be restricted to a few degrees about the median position, whereby the braking force is changed from zero to the maximum braking force required to maintain the desired tension in the flexible material.

FIGS. 3 and 4 show the invention applied to the control of the tension of a multiplicity of wires each being taken from a drum 15. Each drum is provided with a tension monitor unit 16 which comprises guide pulleys 17 and a dancer pulley 18 mounted on arm 19 which is pivoted at 20, and operates the sensing potentiometer P. In this apparatus, the biasing force for the arm is pneumatically obtained using a piston and cylinder 20 which applies a thrust to a bearing 21 mounted on the arm 19. The construction of a preferred form of piston and cylinder assembly is shown in FIG. 4. The piston 22 is sealed to the cylinder 23 by a coated fabric diaphragm 24, and the piston rod is provided with a hard metal cap 25. Compressed air is fed to the cylinder from a reservoir 26 (FIG. 3) from which feeds 27 are taken to the monitor units for other wires. With this arrangement, the biasing force for all the wires can be simultaneously adjusted, by varying the reservoir pressure. In the apparatus of FIG. 3, the electromagnetic brake 28 is mounted directly on the shaft 29 carrying the wire drum.

For both the applications described, an electromagnetic brake of the kind sold by Westool Limited as the "Warner RF Brake" is preferred. It comprises an actuating coil mounted, coaxially with the braked shaft, within an annular channel-shaped steel pole piece having an open end lying in a plane at right angles to the shaft axis closed by a ring of friction material. The friction ring makes contact with a ring-shaped armature capable of sliding axially towards and away from the friction ring on a hub, secured to the shaft, with which the armature is in splined engagement. The armature is pulled into contact with the friction ring by the magnetic force generated in the pole piece upon energization of the coil and bears both against the friction ring and against the edges of the open end of the annular steel pole piece. These edges are designed to wear at the same rate as the friction material so that the magnetic circuit is always closed when the armature is in close contact with the friction material.

Instead of mounting the brake on or gearing it to the shaft on which a supply drum or pad of the flexible material is mounted, it may be mounted on or geared to the shaft of a capstan over which the material passes without substantial slip.

When tension control apparatus in accordance with the invention is applied to a lapping head of the kind in which the flexible material passes from a drum of the material mounted coaxially with the core around which the material is being helically lapped, so that the core passes through the drum, the brake may consist of a friction disc mounted on one end of the drum and acted upon by a solenoid operated brake shoe slidable towards and away from the friction disc in a part of the lapping head that rotates about the core at the lapping speed (i.e. a speed different from the speed of rotation of the drum). The tension sensing device must rotate with the lapping head around the core but it is not necessary for the solenoid to be carried by a rotating part of the head; if it is not, the amplifier input signal must pass through slip rings from a rotating part of the head to a fixed part of the head. We prefer in these circumstances to use a preamplifier mounted on the rotating part of the head and it may be necessary to use a second preamplifier mounted on the fixed part of the head to provide the input for the high gain amplifier energizing the solenoid by which the brake is actuated.

Other forms of variable impedance that can be used instead of the potentiometer P are a strain gauge or a photocell or photocells, for example as described in the above-mentioned patent to Bonikowski.

What we claim as our invention is:

1. Apparatus for controlling the tension in elongated flexible material as it is being drawn in engagement with a rotating member, comprising an electromagnetically operated friction brake acting on the rotating member, a high gain DC amplifier capable of supplying the whole of the electrical power for operating the brake, a sensing device which moves in accordance with changes in tension in the flexible material against a substantially constant biasing force, a variable impedance in the input circuit of the amplifier, means for varying the value of the variable impedance in accordance with the position of the sensing device and means for stabilizing the system to prevent hunting.

2. Apparatus as claimed in claim 1 in which the brake is arranged to act on a shaft and comprises an activating coil mounted, coaxially with the braked shaft, an annular channel-shaped steel pole piece surrounding the activating coil and having an open end lying in a plane at right angles to the shaft axis, a ring of friction material which closes the said open end of the pole piece, a hub secured to the shaft, a ring-shaped armature in splined engagement with the hub and capable of sliding axially towards and away from the friction ring on the hub, the armature being pulled into contact with the friction ring by the magnetic force generated in the pole piece upon energization of the coil.

3. Apparatus as claimed in claim 1 in which the sensing device comprises a pivoted arm, a spring applying a substantially constant biasing force to the pivoted arm, and a dancer roll carried on the pivoted arm.

4. Apparatus as claimed in claim 1 in which the sensing device comprises a pivoted arm, pneumatic means applying substantially constant biasing force to the pivoted arm and a dancer roll carried on the pivoted arm.

5. Apparatus as claimed in claim 1 in which the high gain DC amplifier is a multistage transistor amplifier which comprises an overall feedback circuit directly connecting its output with its input.

6. Apparatus as claimed in claim 1 in which the means for stabilizing the system comprises a resistance-capacitance network in the amplifier input.

7. In a lapping head for helically applying elongated flexible material to a core as it passes axially through the lapping head, apparatus for controlling the tension in the elongated flexible material as it is being drawn in engagement with a rotatable member and applied to the advancing core, comprising an electromagnetically operated friction brake acting on the rotating member, a high gain DC amplifier capable of supplying the whole of the electrical power for operating the brake, a sensing device which moves in accordance with changes in tension in the flexible material against a substantially constant biasing force, a variable impedance in the input circuit of the amplifier, means for varying the value of the variable impedance in accordance with the position of the sensing device and means for stabilizing the system to prevent hunting.

8. Apparatus as claimed in claim 7 in which the sensing device comprises an arm which lies in a radial plane passing through the axis of rotation of the head, is rotatable in that plane about a pivot perpendicular thereto, means for applying a substantially constant biasing force to the arm, a dancer roller carried on the arm, and means for passing a loop of the flexible material over the dancer roller in a direction such that the arm lies substantially perpendicular to said axis when the tension is at its optimum value.

9. Apparatus for controlling the tension in a plurality of lengths of flexible material as they are being drawn in engagement with respective rotatable members, comprising for each length a system comprising an electromagnetically operated friction brake acting on the respective rotatable member, a high gain DC amplifier capable of supplying the whole of the electrical power for operating the brake, a sensing device which moves in accordance with changes in tension in the associated length of flexible material against a substantially constant biasing force, pneumatic means for applying said biasing force, a variable impedance in the input circuit of the amplifier, means for varying the value of the variable impedance in accordance with the position of the sensing device, and means for stabilizing the system to prevent hunting; and a reservoir, common to all of the plurality of systems, for supplying fluid to the said pneumatic biasing means.