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B. M. JONES

2,990,484

POSITION REGULATOR FOR ADJUSTABLE SPEED DRIVES

Filed April 17, 1958

2 Sheets-Sheet 1

FIG 1

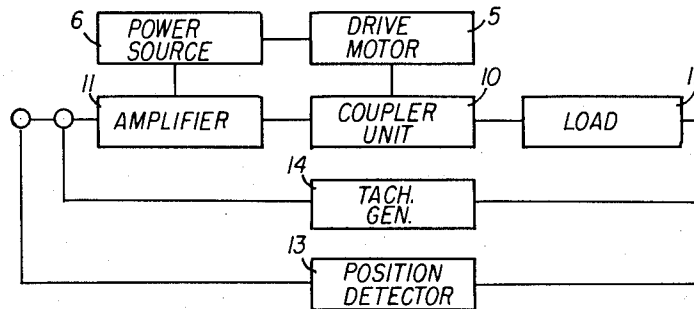


FIG 2

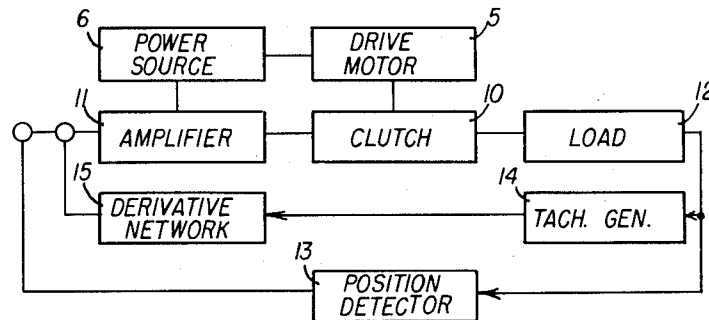


FIG 3

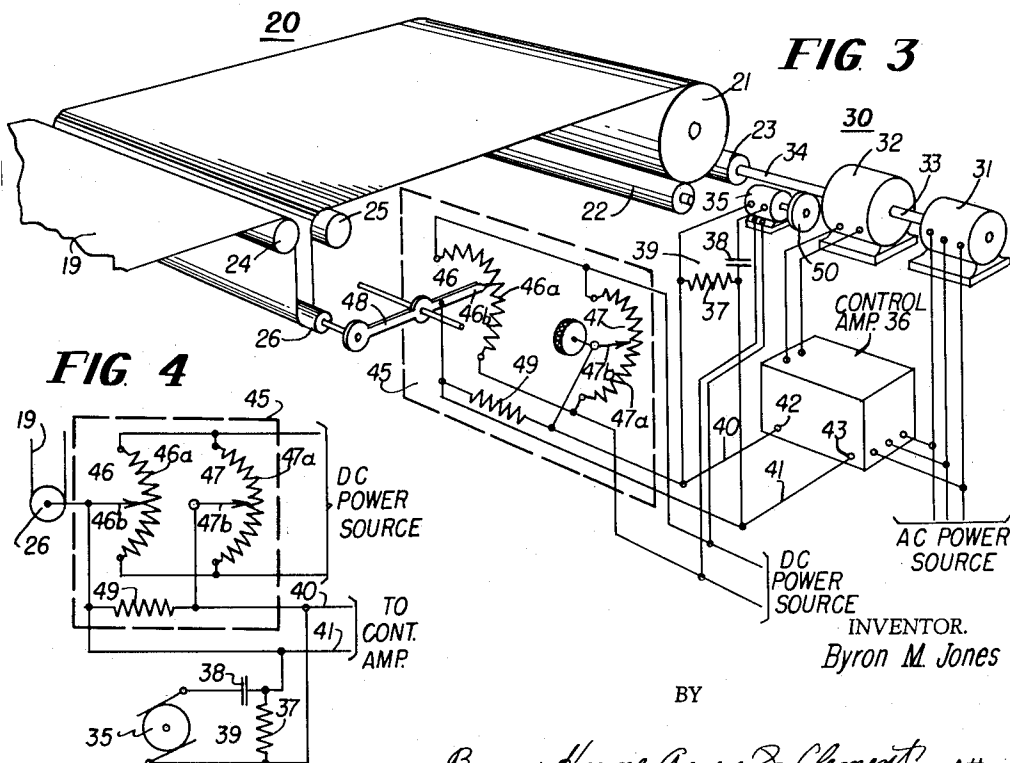
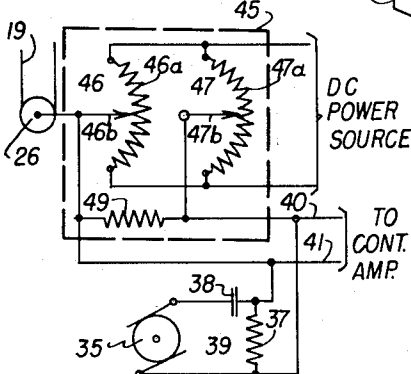


FIG 4



BY

Byron Hume Green & Clement, Attys

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B. M. JONES

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POSITION REGULATOR FOR ADJUSTABLE SPEED DRIVES

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2 Sheets-Sheet 2

FIG 5

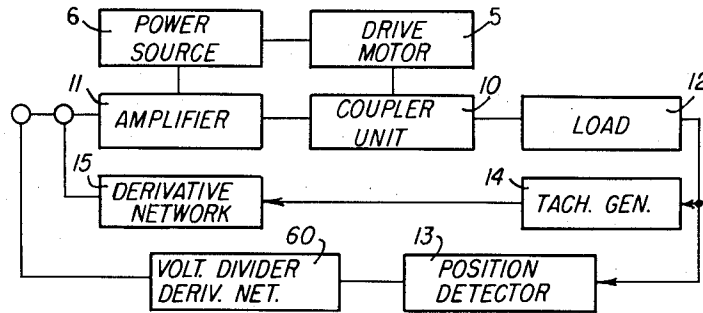
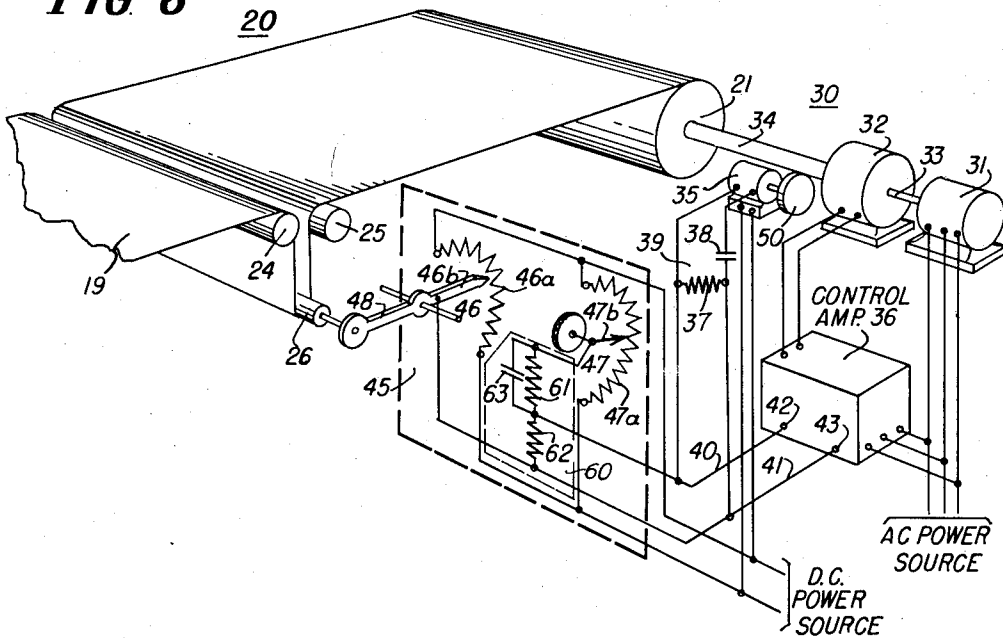


FIG 6



INVENTOR.

Byron M. Jones

BY

Byron Hume Jones & Clement.

Attys.

1

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POSITION REGULATOR FOR ADJUSTABLE SPEED DRIVES

Byron M. Jones, Milwaukee, Wis., assignor to The Louis Allis Company, Milwaukee, Wis., a corporation of Wisconsin

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9 Claims. (Cl. 310-94)

The present invention relates to adjustable speed drives, and particularly to a position regulator control system for adjustable speed drives wherein a magnetic clutch is utilized as the coupler unit.

Adjustable speed electric drives utilizing magnetic clutch coupler units are widely used in commercial operations because of the dependability, long life and the ease of maintenance characteristic of such equipment. It is conventional to provide a plurality of such electrical drives in continuous process operations, such as in the manufacture of paper, wire, synthetic filaments, cloth, and so forth, for conveying the material through various steps of the manufacturing operation. In order to prevent undue stresses on the manufactured material or on conveyor loops carrying the manufactured material during the manufacturing operation, it is necessary that each of these independent electrical drives operate in synchronism with the other electrical drives in the system. Specifically, in a continuous conveyor belt powered by multiple independent electric drives, each drive must be run at a speed related to speed of the conveyor belt so as to hold a fixed position in the loop, otherwise undue tension or slack may be developed in the belt. In a paper-making operation such deviation from the preferred drive position would effect the quality of the paper being manufactured. Similarly, take-up reels and winders associated with a terminal operation in continuous process of the type described must be driven at an exact speed so as to wind or spool the material at the same rate that the material is fed to the spool from the processing machine so that the material is wound on the spool under uniform tension to prevent wrinkles and undue stresses. To accomplish effective position control in such systems, it is necessary to provide each electrical drive with a feedback control that is quickly responsive for correcting any variations between a preferred output and the actual output of the associated magnetic clutch coupler unit.

It is a general object of the present invention to provide an improved position regulator control for magnetic clutch units of adjustable speed drives.

A more specific object of the invention is to provide for an adjustable speed drive incorporating a magnetic clutch, an improved feedback control system for stabilizing the position of the load drive shaft over a wide range of shaft speeds and free from hunting action.

A further object of the invention is to provide for an adjustable speed drive incorporating a magnetic clutch, an improved feedback control system operative from the load drive shaft and responsive to variations in actual shaft position from preferred shaft position and responsive to changes in shaft speed for maintaining the actual shaft position matched to the preferred position.

Another object of the invention is to provide for an adjustable speed drive incorporating a magnetic clutch, an improved feedback control system for maintaining the load drive shaft position matched to a preferred position wherein deviation of the drive shaft from the preferred shaft position is caused by the applied load and is independent of shaft speed.

A further object of the invention is to provide for an adjustable speed drive incorporating a magnetic clutch, an improved feedback control system including a magnetic clutch controller, a shaft position control loop for

2

signalling the controller in accordance with variations of shaft position from a preferred shaft position and a shaft speed control loop for signalling the controller in accordance with variations in shaft speed, thereby to provide a stable feedback loop effective over a wide range of shaft speeds.

Further objects and features of the invention pertaining to the particular arrangement whereby the above objects are attained.

The invention, both as to its structure and manner of operation, will be better understood by reference to the following disclosure and drawings, forming a part thereof, wherein:

FIGURE 1 is a block diagram of a position regulator control system for a magnetic clutch coupler unit as is known in the art;

FIGURE 2 is a block diagram of a position regulator control system for a magnetic clutch coupler unit in accordance with the invention;

FIGURE 3 is a schematic view in perspective showing the position regulator control system in accordance with the invention as it might be employed in an adjustable speed electric drive for a take-up reel in a paper-making machine;

FIGURE 4 is a schematic showing of the shaft position detector and the shaft acceleration detector employed in the arrangement of FIGURE 3;

FIGURE 5 is a block diagram of a variation of the position regulator control system for a magnetic coupler unit in accordance with the invention; and

FIGURE 6 is a schematic view in perspective showing a variation in the position regulator control system in accordance with the arrangement of FIGURE 5 as it might be employed in a paper-making machine take-up reel.

Referring now to the drawings, there is shown in FIGURE 1 a block schematic representation of a position regulator control for a magnetic clutch such as is known in the art. In this arrangement, there is included an electrical drive motor 5 and a power amplifier 11 both energized from a source of power 6, a coupler unit 10 mechanically energized from the drive motor 5 and electrically energized from the amplifier 11, and a load 12 rotatably driven by the coupler unit 10. Connected in parallel between the load member 12 and the control input to the amplifier 10 is a load position detector 13 and a tachometer generator 14. These last two units provide a control feedback between the output of the drive system, that is the rotating load 12, and the input to the drive system, that is the amplifier 11.

The coupler unit is an eddy current coupler, also referred to as a magnetic clutch, of conventional construction including a drive member connected directly to the drive motor 5, a driven shaft member connected to the load 12, and an inductor for providing a coupling flux path between the drive member and the drive shaft member. The speed of the drive shaft relative to the drive member is determined in accordance with the electrical energization provided to the inductor unit. The position detector 13 compares the motion of the load shaft to the motion of a reference and provides an output voltage of a magnitude and polarity corresponding to magnitude and direction of variation in motion between the load shaft and the reference. The motion compared may be in revolutions per minute, linear velocity, angular velocity, acceleration, and so forth, any one of which will provide a measure of shaft position relative to the position of the reference at any instant. The tachometer generator 14 produces a voltage in accordance with speed at which the load shaft rotates.

In this arrangement, the amplifier 11 is under direct and continuous control of the tachometer generator 14

and of the position detector 13 so that within a given limited range of rotational speeds, the actual position of the load shaft may be maintained close to a preferred shaft position. Within the limited speed range, the loop gain of the system can be adjusted so that adequate stability and sensitivity is achieved. However, this is true only for a limited range of rotational speeds and if this range is increased, the gain of the system may become so low as to diminish its sensitivity and if the gain is increased with increase in speed range, at certain speeds the gain will be so high as to render the system unstable. In the former circumstance, the system will tend to be ineffective and in the latter, the system will tend to hunt.

The improved arrangement in accordance with the invention, for overcoming this tendency to hunt, is shown in block schematic form in FIGURE 2. The component parts of the system shown in FIGURE 2 are the same as those used in the system described in FIGURE 1. There is included further a derivative network 15 connected between the output of the tachometer generator 14 and the control input of the amplifier 11. In this arrangement, the loop gain of the system is not adversely influenced by the shaft speed in the required range and the regulator will operate satisfactorily from zero speed to its rated speed, as explained hereinafter.

Giving consideration to the general operation of the arrangement shown in FIGURE 2, when the actual shaft position is matched to the preferred shaft position, the signal from the position detector 13 is in equilibrium and the amplifier 11 produces sufficient energization to the coupler unit 10 so as to maintain this condition of equilibrium. Under these circumstances there is no output from the derivative network 15 to the amplifier 11. However, assuming that thereafter there is some variation in shaft speed, either a positive or a negative acceleration, which tends to produce a change in shaft position from preferred shaft position, the output of tachometer generator 14 will increase or decrease accordingly, producing a transient which is transmitted through the derivative network 15 to the control input of the amplifier 11. The transient so produced is applied to the amplifier so as to effectively damp the system, that is provide negative feedback, and compensate for the acceleration in shaft speed. Assuming that the acceleration in shaft speed has caused a variation in shaft position, the position detector 13 provides an output voltage of a magnitude and polarity in accordance with the magnitude and direction of variation in shaft position from the preferred shaft position which voltage is applied to the control input of the amplifier 11 in such a way as to cause the system to change the shaft speed sufficient so as to restore the shaft position to the preferred shaft position at that instant. For this change in shaft speed caused by a position detector 13, the tachometer generator 14 will produce another transient voltage which is applied through the derivative network 15 to the control input of the amplifier 11 and which signals tend to damp the system from performing any over control on the change in shaft speed. In this arrangement, the amplifier 11 is under primary control of the position detector 13 and the tachometer generator 14 and the derivative network 15 produce a secondary control voltage which effectively stabilizes the system but does not introduce permanent offset at different steady-state speeds so that the system can operate effectively from zero speed to rated speed.

Giving further consideration to the arrangement in accordance with the invention, and referring specifically to FIGURE 3, and the presentation of FIGURE 4, there is shown therein the improved position regulator control system in accordance with the invention as applied to a take-up reel in a paper-making machine. In this arrangement there is illustrated a reel assembly 20 and drive apparatus 30 whereof the reel assembly 20 includes a spool 21 on which the material, here selected to be paper, is to be wound, a pair of revolving drums 22 and

23 on which the spool 21 is supported and revolved by frictional engagement with the drive drum 23, guide rolls 24 and 25 and a dancer roll 26 for taking up slack in the paper roll and for maintaining the tension therein constant at all times thereby to make certain that the paper is wrapped on the spool 21 evenly, smoothly and with constant tension.

The drive system 30 includes an A.C. motor 31, a magnetic clutch 32 including an input shaft 33 driven from the A.C. motor 31 and an output or load shaft 34 extending from the magnetic clutch 32 to the drive drum 23 in the reel assembly 20. Operative from the output shaft 34 by any suitable means, such as a gear drive 50, is a tachometer generator 35 for producing a voltage in accordance with the rotational speed of the output shaft 34. A control amplifier 36 controls the energization to the inductor of the magnetic clutch 32. An A.C. power source supplies power to both the control amplifier 36 and the A.C. motor 31. A control input is supplied to the control amplifier 36 through a derivative network 37 including a capacitor 38 and a resistor 39, connected in the output of the tachometer generator 35. In this arrangement, the capacitor 38 is connected in series and the resistor 39 is connected in shunt with conductors 40 and 41 extending between the output of the tachometer generator 35 and the input terminals 42 and 43 to the control amplifier 36.

A control circuit 45 is also connected to the input terminals of the control amplifier 36 for purposes of influencing the energization in the magnetic clutch 32. This control circuit corresponds to the position detector 13 of FIGURE 2. Specifically, the control circuit 45 includes two potentiometers 46 and 47 of which the resistance elements 46a and 47a are connected in parallel to a source of direct current and which, with the movable arms 46b and 47b, form a bridge balance detector. The output of the bridge balance detector is taken from the arms 46b and 47b and applied to conductors 40 and 41 across a load resistor 49. The potentiometer 47 is a reference potentiometer by means of which position control is adjusted. The potentiometer 46 is associated with the dancer roll 26 and the position of the movable arm 46b varies directly with the supported position of the dancer roll 26. In the arrangement as shown, the bridge detector operates at a fixed unbalance in order to provide across the load resistor the fixed bias required for operating the amplifier. However, it is to be understood that the required fixed bias could be applied directly to the amplifier independent of the bridge detector so that the detector could operate as a balance bridge.

Considering for a moment the manner in which the dancer roll 26 cooperates in the take-up reel action, the dancer roll 26 may be supported by the moving material between the guide rolls 24 and 25. Suspended as it is, the dancer roll 26 applies a constant tension to the moving paper material 19. Under normal operating conditions the distance between the dancer roll 26 and the guide rolls 24 and 25 will remain substantially constant. However, assuming that the material is fed to the guide roll 24 at a constant speed, should the speed of the drive drum 23 and the spool 21 decrease, there would arise a discrepancy between the speeds of the material traveling across the roll 24 and the roll 25, the latter being slower. Thereupon the dancer roll 26 will begin to drop and cause the pivoted lever arm 48 interconnecting the dancer roll 26 and movable arm 46b to vary the position of the movable arm 46b with regards to the fixed resistance 46a in the potentiometer 46. Should the speed of the drive drum 23 suddenly increase, the converse would occur so that the dancer roll 26 would move closer towards the guide rolls 24 and 25 and again the movable arm 46b of the potentiometer 46 would move relative to the fixed resistance 46a thereof, only in the reverse direction to the last-mentioned situation.

From the foregoing, it is to be understood that under

5

proper operating conditions, there will be a fixed equilibrium output voltage across the resistor 49 and the energization to the magnetic clutch 32 from the control amplifier 36 will be maintained substantially constant. However, if because of a change either in the speed at which the paper is fed to the guide roll 24 or the speed at which the paper is drawn past the guide roll 25, is varied, the position of the dancer roll 26 will be changed, causing a change in the position of the movable arm of the potentiometer 46. Thereupon, the condition of the resistance bridge in the control circuit 45 will change and an output voltage different from the equilibrium voltage will appear across the resistor 49 indicating that the spool 21 is not being driven at a proper speed relative to the speed of the paper being fed over the guide roll 24. In broader terminology, it is an indication that the position of the spool 21 has varied from the preferred spool position. Accordingly, the control amplifier 36 will be energized in accordance with the polarity and magnitude of the output voltage across the load resistor 49 so as to adjust the speed of the drive shaft 34 and the connected spool 21 so that the dancer roll 26 will be restored to a position so as to cause the output voltage across the load resistor 49 to be returned to its equilibrium value.

During the period that the control amplifier 36 is responding to controls from the circuit 45 and adjusting energization of the magnetic clutch 32, the tachometer generator 35 and the derivative circuit 37 is responding to the changes in speed of the output shaft 34 and transmitting to the input of the control amplifier 36 signals tending to damp changes in speed taking place in the output shaft 34. This is a transient negative feedback which actually causes the system always to undercorrect and thereby prevent hunting operations from taking place in the system. Because the transient damping signal can be made to be of a high magnitude, a feedback loop of high sensitivity can be used without introducing problems of stability or hunting.

A variation of the drive arrangement shown in FIGURE 3 including means for improving the speed of response of the system is shown in FIGURES 5 and 6. The block schematic representation of FIGURE 5 includes the same elements as shown in the block schematic representation of FIGURE 2 with the addition of a voltage divider-derivative network unit 60 which provides from the output of the position detector a composite signal indicative of both the variation in the position of the drive member from the preferred position at any instant and the rate at which such variation occurs. The actual circuit for this system is shown in FIGURE 6. Therein the output from the bridge detector 45 at the potentiometer arms 46b and 47b is applied to the voltage divider-derivative network unit 60 including resistors 61 and 62 and a capacitor 63 connected in parallel with resistor 61. Under normal equilibrium conditions, the voltage applied to the control amplifier 36 will be in accordance with the voltage across resistor 62. However, under conditions of change when the dancer roll 26 is rising or falling, the voltage applied to the control amplifier from the detector 45 will be the composite of the voltage across resistor 62 and a transient voltage indicative of the rate and direction of change due to the change in the charged condition of the capacitor 63 and the resulting current flow through the resistor 62. The transient voltage will always have the same polarity as the direction of change of voltage across the resistor 62. Accordingly, the control amplifier 36 will be signalled, initially at least, as though the detected change in position is of a greater magnitude than is actual so that there will be a tendency for the amplifier to overcontrol, but this tendency is short lived because the inducing voltage is the transient which soon dies away. Accordingly the speed of response of the system is improved.

The derivative network 37 associated with the tachom-

6

eter generator 35 operates as described above to damp the system and prevent hunting. Inasmuch as the transient output from the unit 60 is not time coincident with the transient output of the network 37, the two transients will cooperate and provide a system characterized as being stable and having a good speed of response.

It is to be noted that in FIGURE 6 the spool 21 is driven directly by the shaft 34 and this arrangement is shown to illustrate the flexibility of the system. It is appreciated that in this arrangement, where the spool 21 is driven directly by the shaft 24 and where the delivery of material to the reel assembly 20 is at a constant rate, the rotational speed of the spool will gradually decrease as the material builds up on the spool. Accordingly, the output voltage from the tachometer generator 35 will gradually fall off. This falling off of voltage will not adversely affect the operation of the system both because the rate of fall-off is small and the time constant of the derivative network 37 is selected so that the voltage appearing across the output thereof and applied to the amplifier therefrom is of a very small magnitude.

It is appreciated that the arrangements shown in FIGURES 3 and 6 are merely exemplary of any one of a number of specific ways in which the system in accordance with the invention may be realized. Additionally, there is no intent to limit the use of this system for take-up reel operations inasmuch as the control system can be employed in any arrangement where servo-equipment may be utilized.

As variations and modifications may be made in the arrangement without departing from the spirit and scope of the invention, it is intended to cover in the appended claims all such variations and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, a coupler device selectively operative for controlling the coupling between said drive motor and said rotatable member thereby to control the speed of said rotatable member, means associated with said rotatable member for providing a first control signal in accordance with any variation in the peripheral position of said rotatable member from a preferred peripheral position at any instant, means for providing a second control signal in accordance with the rate of any change in the speed of said rotatable member, and control means responsive to said first and second control signals for operating said coupler device so as to maintain the peripheral position of said rotatable member matched to the preferred peripheral position at any instant.

2. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, a coupler device selectively operative for controlling the coupling between said drive motor and said rotatable member thereby to control the speed of said rotatable member, positioned detector means for providing a first control signal of a magnitude and polarity at any given instant in accordance respectively to the magnitude and direction of any variation at that instant in the peripheral position of said rotatable member from a preferred peripheral position, means for providing a second control signal of a magnitude and polarity in accordance respectively with the rate and the direction of any change in the speed of said rotatable member, and control means responsive to said first and second control signals for operating said coupler device so as to maintain the peripheral position of said rotatable member matched to the preferred peripheral position at any instant.

3. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, an eddy current coupler device selectively energized for controlling the coupling between said drive motor and said rotatable member thereby to control the speed of said rotatable member, position detector means for providing a

7

first control signal of a magnitude and polarity at any given instant in accordance respectively to the magnitude and direction of any variation at that instant in the peripheral position of said rotatable member from a preferred peripheral position, speed detector means for providing an output voltage in accordance with the rotational speed of said rotatable member, differentiating means for providing a second control signal from the time derivative of said output voltage, and control means responsive to the composite of said first and second control signals for operating said coupler device so as to maintain the peripheral position of said rotatable member matched to the preferred peripheral position at any instant.

4. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, an eddy current coupler device selectively energized for controlling the coupling between said drive motor and said rotatable member thereby to control the speed of said rotatable member, position detector means for providing a first control signal of a magnitude and polarity at any given instant in accordance respectively to the magnitude and direction of any variation at that instant in the peripheral position of said rotatable member from a preferred peripheral position, speed detector means for providing an output voltage in accordance with the rotational speed of said rotatable member, differentiating means for providing a second control signal from the time derivative of said output voltage, and amplifier means provided with a source of electrical power and responsive to said first and second control signals for selectively energizing said eddy current coupler device so as to adjust the peripheral position of said rotatable member to the preferred peripheral position at any instant, wherein said first control signal is applied to said amplifier means so as to provide the feedback control for attaining substantial adjustment between actual position and preferred position and said second control signal is applied to said amplifier means so as to provide damping to the feedback control for preventing hunting action in the feedback loop.

5. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, an eddy current coupler device including a driven member connected to said drive motor and a drive member connected to said rotatable member and an inductor member selectively energized for providing variable coupling between said driven member and said drive member thereby to control the speed of said rotatable member, bridge balance detector means for producing a first control signal of a magnitude and polarity in accordance respectively to the magnitude and direction of any variation in the peripheral position of said rotatable member from a preferred peripheral position, a tachometer generator connected to said rotatable member for producing a direct current output voltage corresponding to the rotational speed of said rotatable member, differentiating means connected across the output of said tachometer generator including a series capacitor and a shunt resistor for providing a second control signal from the time derivative of said output voltage, and amplifier means provided with a source of electrical power and responsive to said first and second control signals for selectively energizing said eddy current coupler device so as to adjust the peripheral position of said rotatable member to the preferred peripheral position at any instant, wherein said first control signal is applied to said amplifier means so as to provide the feedback control for attaining substantial adjustment between actual position and preferred position and said second control signal is applied to said amplifier means so as to provide damping to the feedback control for preventing hunting action in the feedback loop.

6. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, a coupler device selectively operative for controlling the coupling between said drive motor and said rotatable

8

member thereby to control the speed of said rotatable member, position detector means for providing a first control signal of a magnitude and polarity at any given instant in accordance respectively to the magnitude and direction of any variation at that instant in the peripheral position of said rotatable member from a preferred peripheral position, and to the rate and direction at which said variation takes place, means for providing a second control signal of a magnitude and polarity in accordance respectively with the rate and the direction of any change in the speed of said rotatable member, and control means responsive to said first and second control signals for operating said coupler device so as to maintain the peripheral position of said rotatable member matched to the preferred peripheral position at any instant.

7. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, an eddy current coupler device selectively energized for controlling the coupling between said drive motor and said rotatable member thereby to control the speed of said rotatable member, position detector means for providing an output voltage of a magnitude and polarity at any given instant in accordance respectively to the magnitude and direction of any variation at that instant in the peripheral position of said rotatable member from a preferred peripheral position, means connected to said position detector means for providing a first control signal corresponding in composite to the magnitude and polarity of the position detector output voltage and to the rate and direction of change of said position detector output voltage, speed detector means for providing an output voltage in accordance with the rotational speed of said rotatable member, differentiating means for providing a second control signal from the time derivative of said output voltage, speed detector and amplifier means provided with a source of electrical power and responsive to said first and second control signals for selectively energizing said eddy current coupler device so as to adjust the peripheral position of said rotatable member to the preferred peripheral position at any instant, wherein said first control signal is applied to said amplifier means so as to provide the feedback control for attaining substantial adjustment between actual position and preferred position and said second control signal is applied to said amplifier means so as to provide damping to the feedback control for preventing hunting action in the feedback loop.

8. An adjustable speed electrical drive comprising a drive motor, a rotatable member to be driven thereby, an eddy current coupler device including a driven member connected to said drive motor and a drive member connected to said rotatable member and an inductor member selectively energized for providing variable coupling between said driven member and said drive member thereby to control the speed of said rotatable member, bridge balance detector means for producing an output voltage of a magnitude and polarity in accordance respectively to the magnitude and direction of any variation in the peripheral position of said rotatable member from a preferred peripheral position, load means including a first resistor and a second resistor connected in series across the output of said bridge balance detector means and a capacitor connected across said first resistor for providing at the terminals of said second resistor a first control signal corresponding in composite to the magnitude and polarity of the position detector output voltage and to the rate and direction of change of said position detector output voltage, a tachometer generator connected to said rotatable member for producing a direct current output voltage corresponding to the rotational speed of said rotatable member, differentiating means connected across the output of said tachometer generator including a series capacitor and a shunt resistor for providing a second control signal from the time derivative of said tachometer generator output voltage, and

9

amplifier means provided with a source of electrical power and responsive to said first and second control signals for selectively energizing said eddy current coupler device so as to adjust the peripheral position of said rotatable member to the preferred peripheral position at any instant, wherein said first control signal is applied to said amplifier means so as to provide the feedback control for attaining substantial adjustment between actual position and preferred position and said second control signal is applied to said amplifier means so as to provide damping to the feedback control for preventing hunting action in the feedback loop.

9. The adjustable speed electrical drive set forth in

10

claim 8 wherein the impedances in one branch of said bridge balance detector are preselectable and the impedances in the other branch of said bridge balance detector are adjusted in accordance with the time multiple of the detected difference in speed between the peripheral speed of said rotatable member and a reference speed.

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