Feb. 7, 1967 R. L. JAESCHKE ETAL 3,303,367

ELECTRIC DRIVES

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FIG. 1.

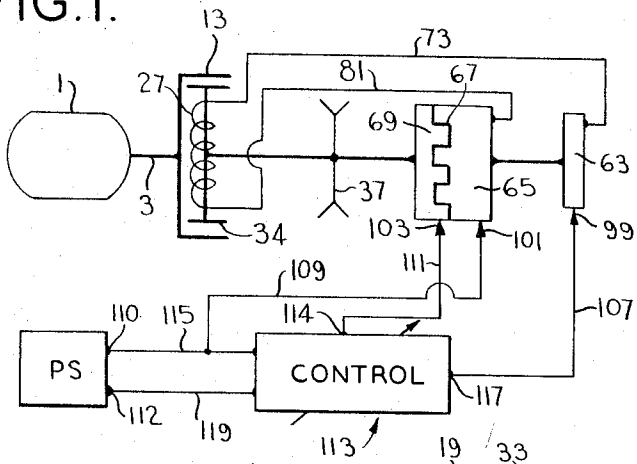
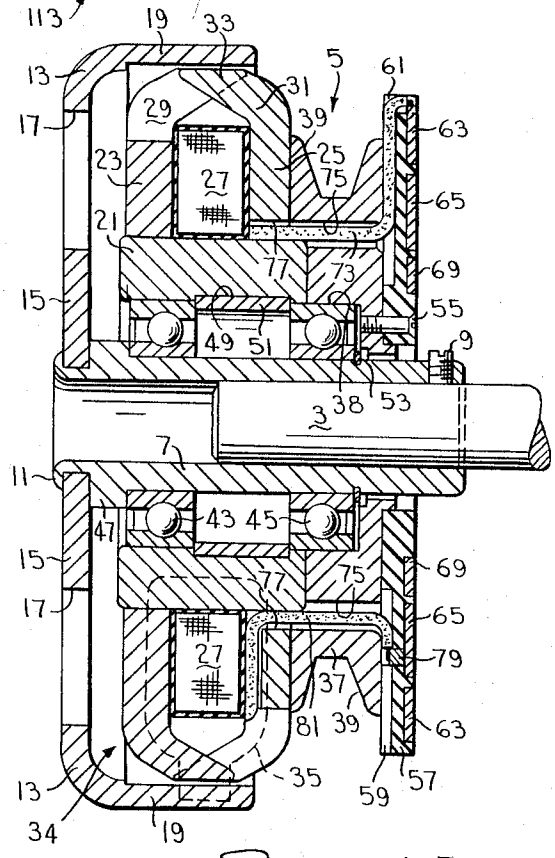


FIG. 3.



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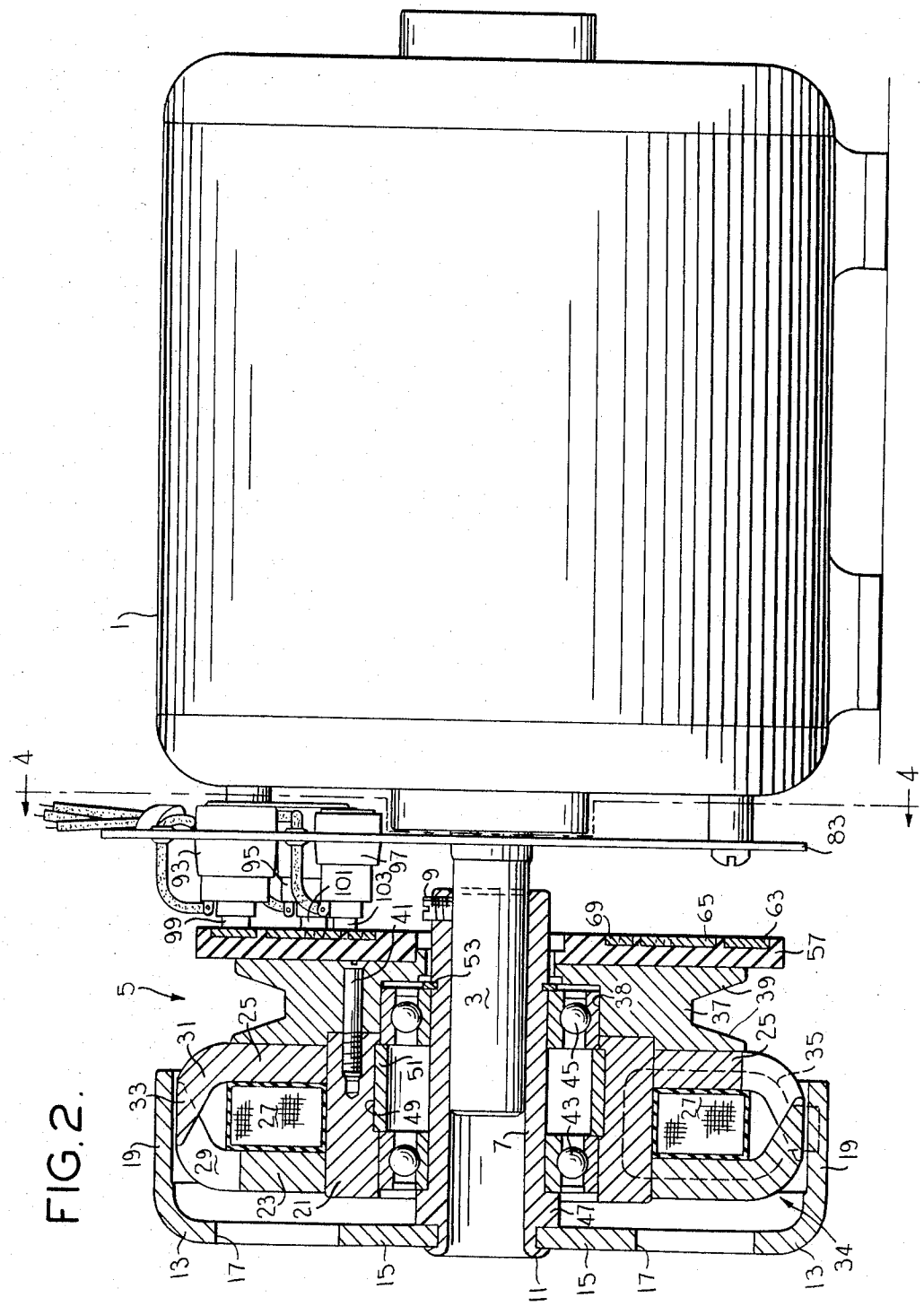


FIG. 2.

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FIG. 5.

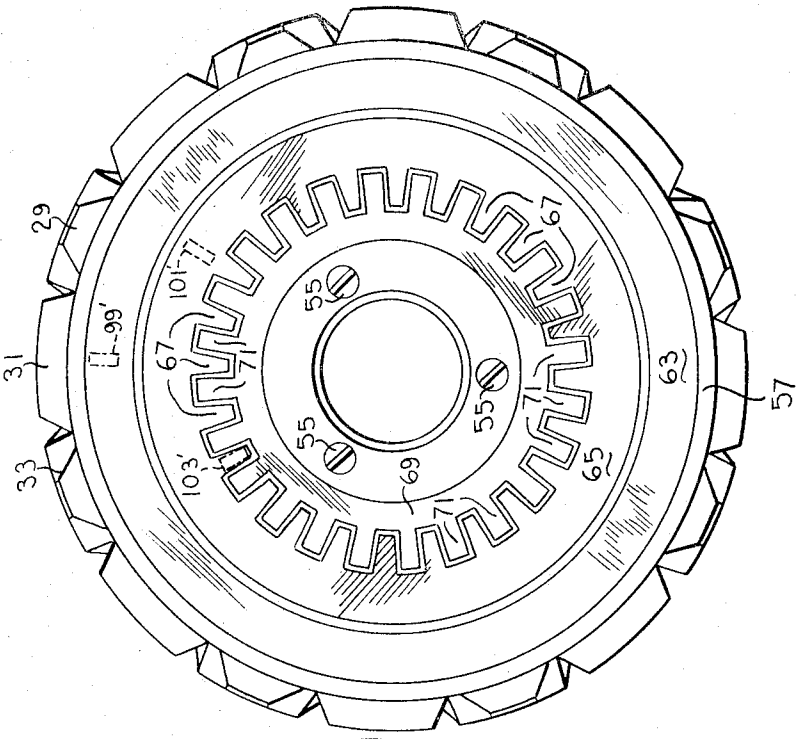
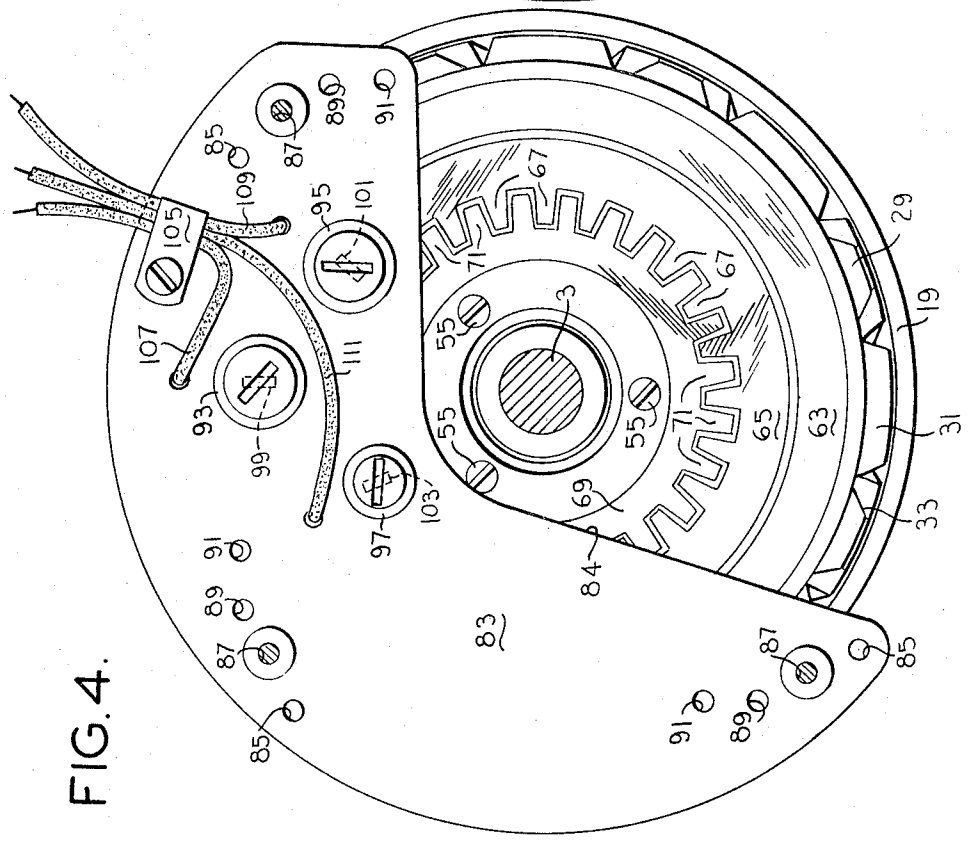


FIG. 4.



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ELECTRIC DRIVES

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Filed Mar. 5, 1964, Ser. No. 349,689
12 Claims. (Cl. 310—95)

This invention relates to electric drives, and with regard to certain more specific features, to regulated, variable-speed, motor-driven eddy-current couplings.

Among the several objects of the invention may be noted the provision of short, compact, variable-speed electric drives which are consistently of high quality but of low cost, providing for the selective incorporation of a given design of eddy-current coupling with any one of a number of desired standard electric motors, preferably but without limitation, of fractional or subfractional horsepower ratings; the provision of an improved form of overhanging and reverted drive between a motor and driven elements in the coupling, incorporating also improved circuit-interrupting and electrical connecting means for control purposes and arranged to favor said short, compact form; and the provision of apparatus of the class described providing quickly replaceable and interchangeable components. Other objects and features will be in part apparent and in part pointed out hereafter.

The invention accordingly comprises the elements and combinations of elements, features of construction, and arrangements of parts which will be exemplified in the structures hereinafter described, and the scope of which will be indicated in the following claims.

In the accompanying drawings, in which one of various possible embodiments of the invention is illustrated,

FIG. 1 is a diagram illustrating the invention, mechanical parts being rearranged for clarity;

FIG. 2 is an axial section through apparatus showing certain mechanical features in their true unique arrangements;

FIG. 3 is a fragmentary axial section in a plane displaced from that of FIG. 2;

FIG. 4 is a cross section taken on line 4—4 of FIG. 2; and

FIG. 5 is an end view of parts forming a driven polar field member of the invention removed from an eddy-current clutch of which it forms a part.

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

Motor-driven eddy-current slip couplings are known, having speed controls which are adjustably self-governing to provide any one of a number of substantially constant output speeds. Such machines have in general been designed for the transmission of substantial amounts of power, and the cost of their manufacture has not been a critical factor in their adoption. On the other hand, to employ such designs for small motor drives such as those in the fractional and the subfractional horsepower field has involved prohibitive costs. By means of the present invention, small variable-speed electric drives of the class described may be manufactured at low cost without sacrifice of high quality of performance. The drives contemplated have applications, for example, to low-power-consuming equipment such as drill presses, coil winders, door operators, furnace controls and the like.

Referring now more particularly to the drawings, there is shown at numeral 1 in an electric motor which may be of the fractional or subfractional size. A ¼ h.p. motor is a typical example of a fractional motor size. A motor of less than ¼ h.p. is within the category of a subfractional size.

The motor has a stub shaft 3. For substantial ranges

of the above-sized motors, a common shaft size is employed and in some cases bushings are used to bring sizes up to diameters of holes in hubs of parts to be attached thereto. Numeral 5 in general indicates an eddy-current clutch or slip coupling operating upon the general principles such as disclosed in my U.S. Patent 2,606,948. However, slip coupling 5, as will appear, is designed for advantageous use for small drives in the power range above indicated. It comprises a central sleeve 7 adapted to be slip-fitted or telescoped over the stub shaft 3 and held in place by a set screw or like fastener 9, located toward its inner end with respect to motor 1 and accessible through the space between the clutch 5 and motor 1.

Attached to the outer end of the sleeve 7 is a cup-shaped steel inductor 13, a press fit and staking as at 11 being employed, for example. The inductor 13 is composed of iron, steel or other magnetizable material in which eddy currents flow when swept by a polarized magnetic field. The inductor has a flat radial portion 15 in which are air-circulating openings 17 and an integral cylindrical portion 19 in which induced eddy currents flow. The enclosing smooth outside form of part 19 provides a safe enclosure even when rotating. As is apparent from the drawings, the inductor 13 may conveniently be cup-shaped by blanking and drawing operations from sheet metal of appropriate gage. Inductor 13 is the driving member of the eddy-current clutch 5. Within the inductor 13 is located a polar field-forming rotor, constituted by a ring or sleeve 21, upon which are press-fitted pole rings 23 and 25, the latter flanking an annular field coil 27 sandwiched therebetween. Extending radially from the pole rings 23 and 25 are pole-forming teeth 29 and 31 which are inclined toward one another and interdigitated at 33. All of parts 21, 23, 25, 29 and 31 are made of iron, steel or other magnetizable material. Interdigitation between the teeth 29 and 31 occurs at a small magnetic gap within the cylindrical portion 19 of the inductor.

When the coil 27 is excited, a toroidal flux field, such as suggested by the dotted lines at 35 at the bottom of FIG. 2, interlinks parts 21, 23, 29, 19, 33, 25 in that or the reverse order, depending upon which direction the current flows in the coil 27. The particular direction is not significant. Hereinafter parts 21, 23, 25, 27, 29 and 31 will be referred to as a field rotor 34. Suitably connected with the ring 21 is a nonmagnetic sheave or pulley 37, composed for example of aluminum and grooved as at 39 to receive a V-belt for effecting a driving connection to whatever apparatus is to be driven. Connecting screws form the attachment between parts 37 and 21, one of which screws is shown at 41. Other connecting means may be used, such as, for example, a press fit.

At numerals 43 and 45 are shown ball bearings for supporting the rotor parts on the sleeve 7. To provide for easy assembly, the sleeve 7 is provided with a shoulder 47 against which the inner race of the bearing 43 may be pressed. This is done before the rotor parts are inserted into the cup-shaped inductor 13. Then before the sheave 37 is attached to ring 21, the latter (carrying parts 23, 25 and 27) is slipped over the outer race of bearing 43. The ring has a groove 49 for the reception of a split spring snap ring 51 which is inserted before bringing the bearing 45 and sheave 37 into position. Then the bearing 45 is slipped onto the sleeve 7 and thereafter the sheave 37, which is recessed at 38 to fit over the outer race of bearing 45. Then sheave 37 is fastened to sleeve 21 by the screws 41. A small snap ring 53 is snapped into a groove in the sleeve 7 which, along with the shoulder 47, holds the members 21 and 37 in proper axial position on sleeve 7. Thus the polar field parts 23, 25, 27, 29 carried by the ring 21 are held in proper position within the part 19 of

the inductor member 13. Wires 73 and 81, to be mentioned, are inserted during assembly.

Attached by screws 55 to the flat right side of the sheave 37 is an insulating plate 57. This plate is radially slotted on its left or inside, as shown at 59 and 61 in FIG. 3. On its right or outside it carries outer and inner individually insulated slip rings 63 and 65, the latter having inwardly directed teeth, as shown at 67. Inside of the inner ring 65 and carried on the insulating plate 57 is another individually insulated ring 69, having outwardly directed teeth 71 which spacedly interdigitate with the teeth 67. The rings 63, 65 and 69 are sunk into the face of the plate 57 in a manner such that not only is each insulated from the other but also such that the right-hand face of the plate 57 and the face of the rings 63, 65 and 69 are flush. As will appear, it is necessary that the rings 63 and 65 be conductive and they are therefore composed of copper, for example. The ring 69 is not required to be conductive for reasons which will appear but it is preferably also composed of copper.

As shown in FIG. 3, a wire 73 connects slip ring 63 with one end of the coil 27. In doing so, it passes through the said slot 61 and through openings 75 and 77 provided in the sheave 37 and pole ring 25, respectively. The slip ring 65 is provided with a conductive terminal 79 which extends through plate 57 into the groove 59. A wire 81 connects this terminal and hence the slip ring 65 with the other end of the coil 27. Additional ones of the openings 75 and 77 accommodate passage of this wire 81. As above stated, wires 73 and 81 are connected during assembly of the parts in which they are located.

At numeral 83 is shown an electrical harness plate member designed to assume a flatwise radial aspect between the motor 1 and coupling 5. Plate 83 is provided with four sets of three holes each. The holes in the respective sets are numbered 85, 87, 89 and 91. Each set is at a different distance from a virtual center on the center line of shaft 3 when assembled. Fractional and subfractional horsepower motors have standard frames of varying sizes. Each usually carries a set of four bosses at 90° intervals and at a radius which may depend upon the motor size. Three of the bosses provide for appropriate screw-fastening means. Thus an appropriate one of the sets of three openings 85, 87, 89 or 91 may be used to attach the harness plate 83 to three bosses of the end bell of any standard fractional or subfractional horsepower motor frame or housing.

The harness plate 83 supports three brush assemblies 93, 95 and 97, each of which incorporates conventional spring-pressurizing means (not shown) for axially sliding brush components 99, 101 and 103. Brush components 99 and 101 resiliently contact the slip rings 63 and 65, respectively, in their non-toothed portions, as indicated by dotted lines at 99' and 101' (FIG. 5). Brush component 103 in one angular position of the plate 57 contacts teeth 67 of slip ring 65, as shown by dotted lines 103' in FIG. 5. In this position the brush 103 (on a tooth of ring 65 at 103') is in conductive connection with brush 101 (on ring 65 at 101'). In another position of the plate 57, the brush 103 contacts the teeth 71 of the inner insulated ring 69. In this condition the brush 103 is disconnected from the ring 65. The harness plate 83 also carries supporting means 105 for wires 107, 109 and 111 connected with the brushes 99, 101 and 103, respectively.

It is to be noted that the ring 69 supplies a purely mechanical function. Obviously the space between the teeth 67 on ring 65 could be infilled simply by the insulating material composing the plate 57. In such case, however, unequal wear by the brush on the copper teeth 67 and the insulation therebetween would cause erosion between teeth and deleterious action on the brush. By using the copper teeth 71 of the ring 69, located in the spaces between teeth 67, the brush 103 will more continuously be contacting the same kind of wear surface, namely copper. The result is a better wearing condition for brush 103. It will be understood that the sets of teeth 67 and 71 are sunk into the insulation of plate 57 so that a thin zig-zag separating band of insulation is interposed (FIG. 5).

Referring to schematic FIG. 1, wherein like numerals designate like parts, there is shown a D.C. power supply PS having a pair of terminals 110 and 112, and a speed control unit 113 for variably energizing field coil 27 to maintain the angular velocity of the field member or rotor 34 substantially equal to a preselected value under conditions of varying load on the sheave 37. Control 113 includes means for preselecting a desired angular velocity of sheave 37. The particular circuitry of control 113 forms no part of this invention, but if further details regarding an improved form are desired, they may be found in the copending application of Aubrey H. Smith, Serial No. 349,707, for Control for Electrical Coupling Apparatus, eventuated as U.S. Patent 3,252,022.

Terminal 110 of power supply PS is commonly connected via a conductor 115 to control 113 and via conductor 109 to brush 101, thereby supplying a D.C. potential and D.C. power to both control 113 and slip ring 65, the latter being connected to one side of field coil 27 by means of wire 81. Brush 103 is maintained in contact with the interdigitated insulated teeth 67 and 71, which provide alternate conducting portions (teeth 67) and insulated portions (teeth 71) relative to slip ring 65. As sheave 37 is rotated, brush 103 is sequentially connected to and disconnected from slip ring 65, the teeth 67 of which constitute (together with brush 103) a commutator or circuit-interrupting means. Slip ring 65 is continuously connected to terminal 110 of PS through brush 101 and conductors 109, 115. Brush 103 is connected to an input 114 of control 113 by a wire 111. A series of D.C. voltage pulses (square waves) is supplied to control 113. The frequency or repetition rate of these D.C. voltage pulses is a function of the angular velocity of sheave 37, and constitutes an intermittent control signal applied to input 114. The current path to field coil 27 is completed through conductor 73 which is connected to slip ring 63, brush 99 and wire 107 which is connected to an output 117 of control 113, and a wire 119 which interconnects power supply terminal 112 to control 113. Control 113 is responsive to the frequency of the D.C. square-wave pulses fed to its input 114 to vary the average current supplied to field coil 27 and thereby correct any incipient variations in the angular velocity of sheave 37 relative to any preselected angular velocity. Preferably the field coil current supplied by control 113 is a series of D.C. current pulses having periods or widths which vary in response to the frequency or repetition rate of the control signal.

Operation is as follows:

When the motor 1 is energized, its shaft 3 turns at an approximately constant speed and drives the inductor 13. This in turn drives the field rotor 34, the sheave 37, and the slip rings 63, 65 and ring 69. Since under starting conditions the interdigitated teeth 67 and 71 are moving slowly, the control signal supplied by the circuit interrupter via brush 103 and wire 111 to input 114 will have a low frequency or repetition rate. Because of the low frequency of the control signal and the circuitry of control unit 113, a comparatively high average current is drawn through the circuit PS, 112, 119, 113, 117, 107, 99, 63, 73, 27, 81, 65, 101, 109, 115, returning to PS at terminal 110. This high average current supplied to field coil 27 thereby effects a strong magnetic coupling between inductor 13 and field rotor 34. This accelerates the driven sheave 37 which is connected to the load. With increase in speed, the interruption rate of the circuit interruptor will increase, thus increasing the frequency of the control signal pulses fed to input 114 of control 113. In response to this control signal the average level of power supplied to coil 27 by control 113 is reduced, thus decreasing the electromagnetic coupling between the driv-

ing and driven members until a state of slip is reached which corresponds to the substantially constant speed desired at the sheave **37**. Thereafter, any incipient variation in the angular velocity of sheave **37** is immediately corrected by the servo action of the circuit interrupter, control signal and control **113** varying the average field coil current to compensate for this incipient variation.

In FIG. 1 the slip rings **63**, **65**, ring **69**, and the interdigitating teeth upon which brush **103** rides are, for diagrammatic purposes, shown as being axially directed between cylindric rings. While the use of such rings is possible in the present invention, by having them radially formed as flat rings in a radial plane I am enabled to obtain, in a convenient overhung structure, a shorter and more compact drive (see FIG. 2). This, taken with the provision of the flatwise, radially extending harness plate **83** closely sandwiched in the small space between the closely coupled overhung clutch **5** and motor **1**, makes a very compact unit for small motor applications. Compactness is also favored by the reverted character of the power train from the motor **1** to the sheave **37**. Thus power is transmitted from motor **1** axially out through shaft **3** and sleeve **7**, radially out through **15**, axially back through **15**, radially inward to sleeve **21** and finally axially back toward the motor as the power take-off sheave **37** is reached. This reverted arrangement further contributes to a short length of the apparatus. Short length is also favored by the flat form of the commutator assembly on the plate **57** and the flatwise, radially extending, axially thin electrical harness between the motor and the radially disposed flatwise commutator assembly.

Additional advantages of the invention are in the simplicity with which the final assembly may be made between an assembled clutch and any one of a number of in-stock small motors **1** which may be any of various sizes. Thus all that is necessary for final assembly is to select a motor **1**, apply to its end bell a harness plate **83** carrying the brush assemblies **93**, **95** and **97**. The brushes then extend axially, being spring-biased in the usual manner for resilient commutator engagement. Then a sleeve **7**, having the clutch, sheave and slip ring parts preassembled thereon, is as a unit simply pushed onto the motor shaft **3** until the slip rings resiliently engage the axially protruding brushes **99**, **101** and **103**, after which the fastener **9** is tightened. The unit is then ready for use when the wires **107**, **109**, **111** are appropriately connected to the control **113** and power supply PS. For any off-size shaft **3**, a conventional bushing may be used.

Another advantage of the invention is that the clutch is easily removable from the motor for repairs. The harness plate **83** is quickly removable for brush replacements. The bight **84** therein permits sidewise removal without clutch removal and also permits bottom and sidewise access to the commutator.

In view of the above, it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various constructions could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electric drive comprising an electric slip coupling having a driving inductor member and a driven polar field member, a motor connected with said driving member, a field coil in the field member, an electrical speed control for variably energizing said coil, a source of electrical power having first and second terminals, first and second conductive slip rings carried by said field member and respectively electrically connected across said field coil, each of said slip rings having a continuous peripheral portion, said second slip ring also including circuit-interrupting means, first and second stationary brushes contacting the continuous peripheral portions of said first and second slip rings, said second brush connected with said first terminal, and a third stationary brush connected to an input of said speed control and contacting said circuit-interrupting means intermittently electrically to interconnect said second slip ring and said third brush to supply an intermittent control signal to said speed control input, said second power supply terminal being interconnected to said speed control, said speed control having an output connected to said first brush whereby the field coil is variably energized by said control to maintain a substantially constant angular velocity of said driven member.

2. An electric drive comprising an electric slip coupling having a driving inductor member and a driven polar field member, a motor connected with said driving member, a field coil in the field member, an electrical speed control for variably energizing said coil, a source of electrical power having first and second terminals, first and second conductive slip rings carried by said field member and respectively electrically connected across said field coil, each of said slip rings having a continuous peripheral portion, said second slip ring also having marginal interrupting means formed by spaced marginal teeth, first and second stationary brushes contacting the continuous peripheral portions of said first and second slip rings, said second brush connected with said first terminal, and a third stationary brush connected to an input of said speed control and contacting said second slip ring at its interrupting means intermittently electrically to interconnect said second slip ring and said third brush to supply an intermittent control signal to said speed control input, said second power supply terminal being interconnected to said speed control, said speed control having an output connected to said first brush whereby the field coil is variably energized by said control to maintain a substantially constant angular velocity of said driven member.

3. An electric drive comprising a motor having a stub shaft, an electric slip coupling having a driving inductor member carried on a sleeve fitted to said stub shaft and having a driven polar field member carried on and surrounding said sleeve, a field coil in the field member, an electrical support on the motor for axially directed first, second and third brushes, an electrical speed control for variably energizing said coil, a source of electrical power having first and second terminals, first and second radially flat conductive slip rings carried by said field member to engage said axially directed brushes and respectively electrically connected across said field coil, each of said slip rings having a continuous peripheral portion, said second slip ring also having radially directed marginal interrupting means formed by spaced marginal teeth, said first and second stationary brushes contacting the continuous peripheral portions of said first and second slip rings, said second brush connected with said first terminal, and said third stationary brush connected to an input of said speed control and contacting said circuit interrupting means intermittently to electrically interconnect said second slip ring and said third brush to supply an intermittent control signal to said speed control input, said second power supply terminal being interconnected to said speed control, said speed control having an output connected to said first brush whereby the field coil is variably energized by said control to maintain a substantially constant angular velocity of said driven member.

4. An electric drive comprising a motor having a stub shaft, an electric slip coupling having a driving inductor member carried by a sleeve on said shaft and a driven polar field member carried on said sleeve, said field member including power take-off means, a field winding in the field member, a speed control circuit forming part of a power supply circuit for said winding, a commutator assembly on the field member carrying first and second insulated conductive slip rings, each of which has a con-

tinuous peripheral portion and one of which has an interrupted peripheral portion, first, second and third stationary brushes, the first brush being continuously contacted by the continuous peripheral portion of the first slip ring, the second brush being continuously contacted by the continuous peripheral portion of the second slip ring, said first and second brushes completing the circuit from the power supply through said control circuit and said field winding, said third brush being positioned to be discontinuously engaged by the interrupted portion of the second slip ring and being connected with said control circuit to provide an intermittent control signal for said speed control circuit.

5. An electric drive comprising an electric motor having a stub shaft, a sleeve on said shaft, an inductor carried on the sleeve, said inductor having a radial part and an axial cylindrical part extending toward the motor, a field pole assembly including a field coil, said field assembly being mounted for rotation on and around said sleeve, the poles of said field assembly being surrounded by said cylindrical part of the inductor, said field assembly including a power take-off sheave and a commutator assembly the latter being adjacent the motor of said sleeve, said commutator assembly comprising a radially extending insulating plate supporting first and second slip rings facing the motor, the second ring having an interrupted margin, an electrical harness attached to the end of the motor and supporting first, second and third axially directed brushes a first one of which is engageable with the first slip ring, a second one of which is engageable with the second slip ring and a third one of which is engageable with the interrupted margin of the second slip ring.

6. An electric drive comprising a motor having a housing and a stub drive extending from one end, an eddy-current slip coupling having a driving inductor member and a driven field member, the latter including a field winding, the driving member having a central sleeve extending through the driven member and having a telescoping attachment to said tub shaft, a radially extending harness member attached to the motor housing and located between the housing and the field member of the coupling, said harness member supporting leads to power and control circuits, axially projecting first, second and third brushes and wiring therefor mounted on said harness member, a radially disposed insulating commutator support on the field member adjacent to said harness member and carrying first and second flat-faced slip rings, one of which rings is continuously engaged under axial contact pressure by the first of said brushes and the other of which rings is continuously engaged by the second of said brushes to form a power supply from the power supply circuit through the field winding of the driven member, one of said rings having an interrupted part formed for intermittent engagement by the third brush, said third brush having a connection with said control circuit to provide a control signal.

7. Electric drive apparatus for interchangeable attachment to a number of different driving-motor frames of motors having stub shafts, comprising a driven rotatable field member including a radially disposed insulating commutator plate attached thereto at one side, said plate supporting several radially substantially flat commutator rings which face axially toward any attached frame, an inductor member carried on a sleeve extending through the field member, said inductor member being attached to the sleeve at the side of the field member opposite the commutator plate, an electrical harness comprising a supporting plate which is disposed substantially flatwise and including means for attaching the same to any one of various motor frames and in parallel disposition to the commutator plate said supporting plate supporting several brushes for axially directed engagement with said commutator rings when the plate is attached to a motor frame and the sleeve is telescoped on the corresponding motor shaft.

8. Electric slip coupling apparatus for interchangeable attachment to a number of different motors having different motor frames; comprising a field member having an annular field coil flanked by poles mounted on a first sleeve, a sheave attached to one end of the sleeve, a radially disposed insulating commutator plate attached to the sheave and supporting several substantially flat commutator rings wired to the field coil, said rings facing axially away from the field member, bearing means supporting said first sleeve on a second central sleeve passing through the field member, said second sleeve supporting a cup-shaped inductor member having a radial part adjacent the end of the first sleeve which is opposite to its point of attachment with the sheave, said inductor including a marginal cylindrical portion surrounding said poles, the open end of the cup shape being directed toward said sheave, an electrical harness comprising a supporting plate adapted to be disposed substantially flatwise in a radial direction between a motor and an attached field member and including means for attaching the same to various motor frames, said plate supporting brushes for axially directed engagement with said commutator rings.

9. Electric slip coupling apparatus according to claim 8, wherein each of a first and a second one of said commutator rings has a continuous-peripheral portion for engagement by first and second brushes respectively, the inner one of which has an interrupted inner margin interdigitating with but insulated from an interrupted outer margin of the third innermost ring for engagement in the interdigitating region by a third brush.

10. An electric drive comprising a motor having a stub shaft extending from one end, an electrical harness member for attachment to said end of the motor, said harness member carrying axially disposed brushes, an eddy-current clutch comprising a cup-shaped inductor having its open end directed toward the motor and having a central sleeve for support on said shaft, said central sleeve forming a rotary support for a driven assembly formed by a polar field member, a sheave and a radially disposed insulating commutator plate which are axially joined, the polar field member lying within the inductor, the commutator plate being disposed adjacent said harness member, the sheave being located between the polar field member and the commutator plate, and radially disposed commutator rings carried by said commutator plate engaging said brushes.

11. An electric drive comprising a motor having a stub shaft extending from one end, a radially disposed electrical harness plate attached to said end of the motor and having a bight accommodating passage of said shaft, said plate carrying axially disposed brushes, an eddy-currrent clutch comprising a cup-shaped inductor having its open end directed toward the motor and having a central sleeve for support on said stub shaft, said central sleeve forming a rotary support for a driven assembly formed by a polar field member, a sheave and a radially disposed insulating commutator plate which are axially joined, the polar field member lying within the inductor, the commutator plate being disposed adjacent said harness plate, the sheave being located between the polar field member and the commutator plate, and radially disposed commutator rings carried by said commutator plate engaging said brushes.

12. An electric drive comprising a motor having a stub shaft extending from one end, an electrical harness plate, said harness plate attached to said end of the motor and having a bight accommodating passage of said shaft, said plate carrying axially disposed brushes, an eddy-current clutch comprising a cup-shaped inductor having its open end directed toward the motor and having its closed end perforated for air circulation, said inductor having a central sleeve for support on said stub shaft, said central sleeve forming a rotary support for a driven assembly composed of an axially joined polar field member having interdigitating poles within the inductor and receiving

circulating air from said perforations, said drven assembly also including a sheave and a radially disposed insulating commutator plate, the commutator plate being disposed adjacent said harness plate and the sheave being located between the polar field member and the commutator plate, and radially disposed commutator rings carried by said commutator plate engaging said brushes.

No references cited.

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