Jan. 22, 1952 A. WINTHER 2,583,523

MAGNETIC TORQUE APPARATUS

Filed Aug. 26, 1946 3 Sheets-Sheet 1

FIG. 2.

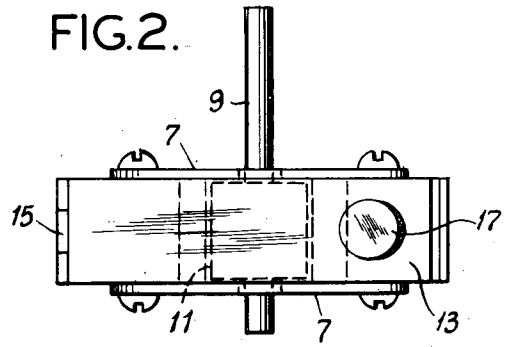


FIG. 1.

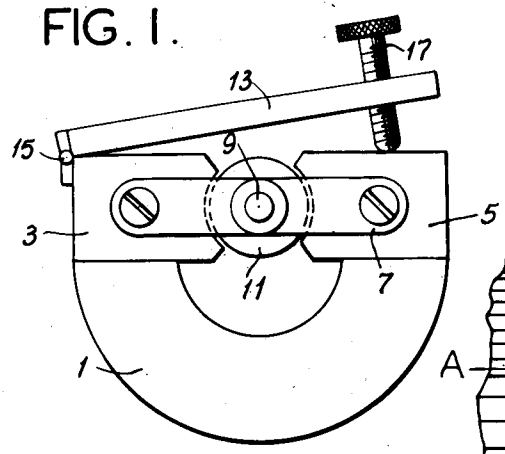


FIG. 3.

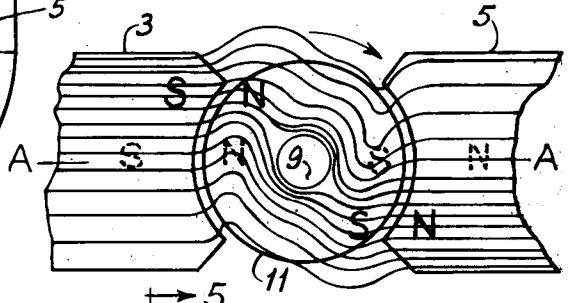


FIG. 5.

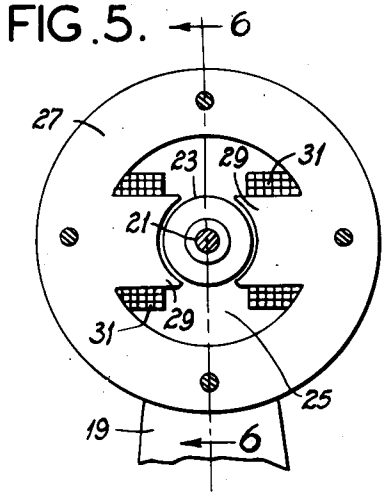
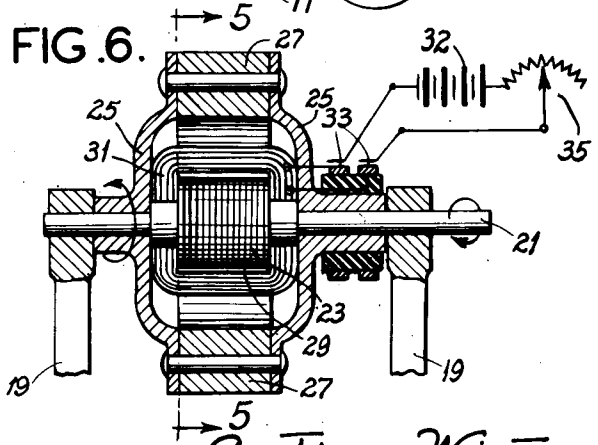


FIG. 6.



Anthony Winther
Inventor.
Haynes and Koenig,
Attorneys.

Jan. 22, 1952 A. WINTHER 2,583,523

MAGNETIC TORQUE APPARATUS

Filed Aug. 26, 1946 3 Sheets-Sheet 2

FIG. 8.

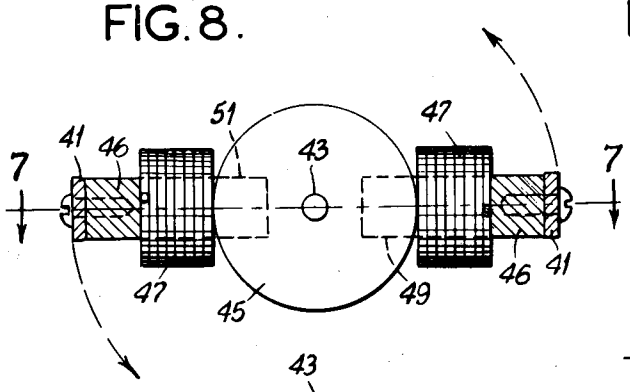


FIG. 4.

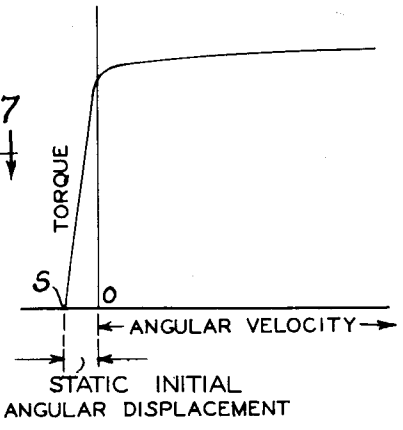


FIG. 7.

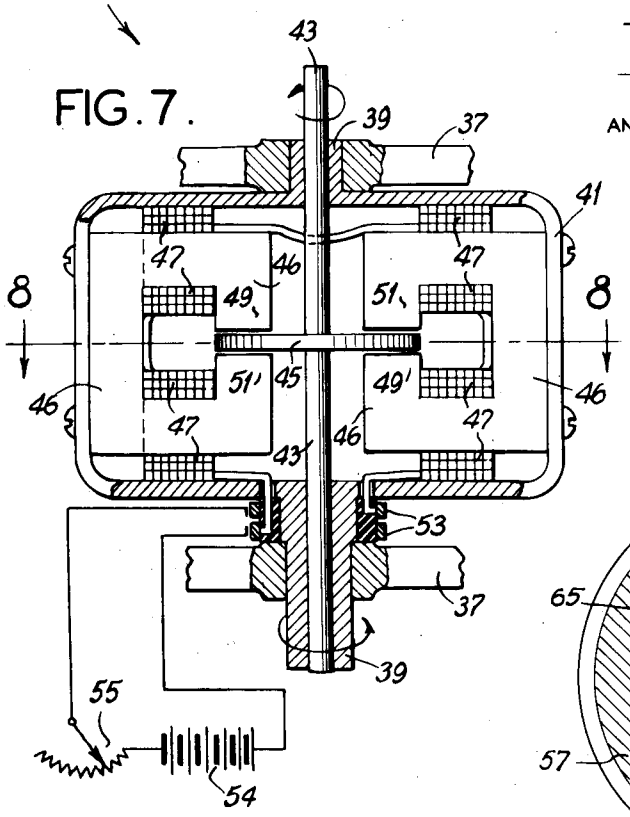
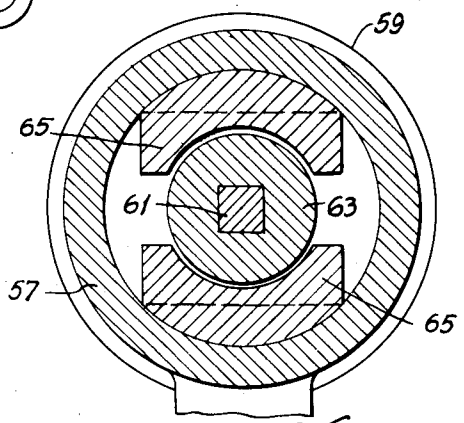


FIG. 10.



Anthony Winther,
Inventor.
Haynes and Long,
Attorneys.

Jan. 22, 1952 A. WINTHER 2,583,523

MAGNETIC TORQUE APPARATUS

Filed Aug. 26, 1946 3 Sheets-Sheet 3

FIG. 9.

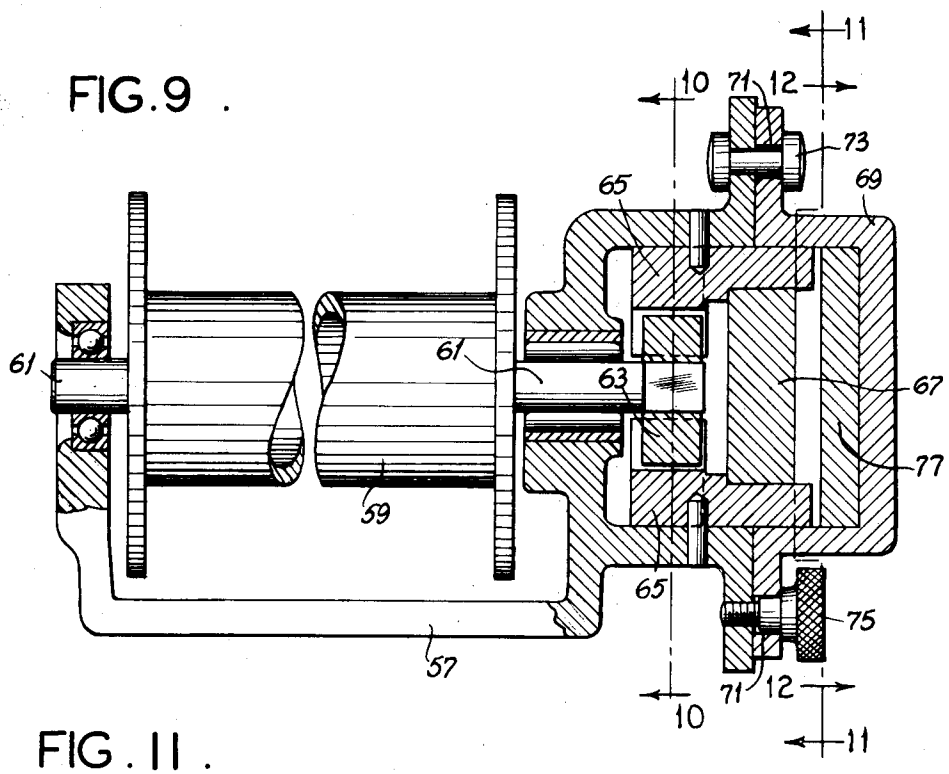


FIG. 11.

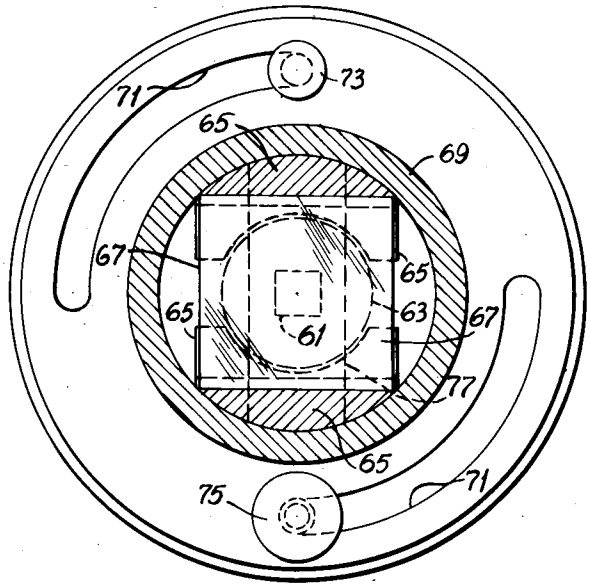
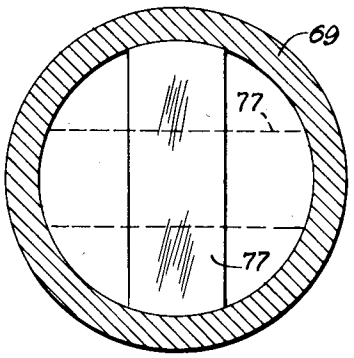


FIG. 12.



Anthony Winther
Inventor.
Haynes and Koenig
Attorneys.

Patented Jan. 22, 1952

2,583,523

UNITED STATES PATENT OFFICE

2,583,523

MAGNETIC TORQUE APPARATUS

Anthony Winther, Kenosha, Wis., assignor to Martin P. Winther, as trustee, Waukegan, Ill.

Application August 26, 1946, Serial No. 693,056

5 Claims. (Cl. 172—284)

1

This invention relates to magnetic torque apparatus, and with regard to certain more specific features, to a magnetic coupling for clutches, brakes, dynamometers and the like.

Among the several objects of the invention may be noted the provision of a magnetic coupling between elements, in which a high and, if desired, constant torque may be obtained over a wide range of slip speeds of said elements, including zero slip speed; the provision of a coupling of the class described in which there is no energy lost in the coupling if the load does not exceed the static holding power of the device, said static holding power being high; the provision of a coupling of this class in which predetermined torque values, including constant values, may be effected under slip conditions involving torques above the static holding torque; the provision of apparatus of this class which in operation under both static and slip conditions stores some energy which after operation becomes useful upon its recovery, for example, to prevent backlash in various apparatus; and the provision of apparatus of this class which is particularly useful when applied to tension control on reels, weaving, drawing, spooling machines and the like. Other objects will be in part apparent and in part pointed out hereinafter.

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 the application of which will be indicated in the following claims.

In the accompanying drawings, in which several of various possible embodiments of the invention are illustrated,

Fig. 1 is an end elevation of an elementary form of the invention;

Fig. 2 is a top plan view of Fig. 1;

Fig. 3 is an enlarged diagrammatic view of certain parts of Figs. 1 and 2, illustrating certain functions believed to occur;

Fig. 4 is a curve showing certain torque-displacement relationships;

Fig. 5 is a sectional view of another form of the invention, being taken on line 5—5 of Fig. 6;

Fig. 6 is a longitudinal section taken on line 6—6 of Fig. 5;

Fig. 7 is a longitudinal section of another form of the invention, being taken on line 7—7 of Fig. 8;

Fig. 8 is a vertical section taken on line 8—8 of Fig. 7;

2

Fig. 9 is a longitudinal section (partly in elevation) of a reel embodying one form of the invention; and,

Figs. 10, 11 and 12 are vertical sections taken on lines 10—10, 11—11 and 12—12, respectively, of Fig. 9.

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

Electromagnetic couplings have heretofore been used wherein the coupling action was effected primarily by magnetic reactions from engendered eddy currents. Such couplings were effective to transmit torque only under conditions of slip movement between the driving and driven elements. The torque-transmitting functions of the present invention are made to depend upon other factors than merely eddy-current losses, although the effects of the latter may be taken advantage of, if desired. The result is the ability of the present device (1) to transmit torque without slip up to a certain torque value, and thereafter (2) to transmit either a constant or a rising torque with slip, as desired. In addition, the device under condition (1) exerts a restorative torque action without dissipation of energy.

Referring now more particularly to Figs. 1 and 2, numeral 1 indicates a strong, permanent horseshoe magnet providing a strong magnetic field. A permanently polarized "Alnico" magnet is satisfactory. Attached are oppositely located taper pole pieces 3 and 5, composed, for example, of soft iron. Soft iron is exemplary of any material which has a high magnetic permeability but preferably of low retentivity, that is, it accepts a dense flux which may be easily coerced so that flux change or distortion therein may easily be accomplished. The purpose of this is that a pole shift may easily be made to occur, as will appear. However, the pole pieces retain their respective polarities. Between the pole pieces 3 and 5 are non-magnetic bearing plates 7 providing bearings for a shaft 9 which carries a rotor 11. This rotor 11 is composed of magnetic material having the characteristics of high remanence and high retentivity; that is, it is difficult to coerce so that flux change or distortion therein is difficult. A suitable material for the rotor is "Alnico V" metal, chilled cast iron or the like. The rotor is not polarized before assembly and receives polarization only by magnetic induction from the pole pieces 3 and 5. "Alnico" is, in general, a sintered alloy containing iron, aluminum, nickel and cobalt. It is to be understood that other similar alloys having

corresponding properties may be suitable and that the terms "Alnico" and "Alnico V" are used simply to designate suitable material that can be obtained in the electrical trade. The rotor **11** is cylindric, having relatively uninterrupted faces opposite the pole pieces **3** and **5**, thus providing a relatively smooth surface into which may enter concentrated flux from said pole pieces **3** and **5**. The rotor **11** may be laminated or non-laminated as desired, a non-laminated construction being shown in Figs. 1 and 2. The effects of laminations or their absence will be discussed below. It will be additionally noted that the pole pieces **3** and **5** have faces which envelope the cylindric inductor member **11** over a substantial portion of its periphery, for example, about half the periphery.

At numeral **13** is shown a magnetic bar hinged to one of the poles **3** by a magnetic hinge **15** and having a magnetic adjustable screw support **17** on the other pole **5**. Since all of the members **13**, **15** and **17** are magnetic, this provides an adjustable by-pass for the magnetic circuit which otherwise would all pass between poles **3** and **5** through the rotor **11**. The higher the bar **13** is adjusted the less by-passage of the flux is accommodated, and vice versa. This device serves as a torque control means when the indicated permanent magnet field means is used.

Figs. 3 and 4 are diagrams which will aid in an understanding of the operation of the invention. In diagrammatic Fig. 3 the magnetic by-pass means has been eliminated. Assume that under the magnetizing influence of the magnet **1**, the field pole **3** is south and the field pole **5** is north. The induced poles in the rotor **11** will be of opposite polarities. If the rotor **11** is not rotating, these poles will all lie up on line A—A and no torque will be exerted (see the dotted letters N and S). If the rotor **11** is turned by means of shaft **9** in the clockwise direction (Fig. 3), the induced poles N and S in the rotor will tend to move to the angular position shown by the solid letters N and S in the rotor. Since the material of the rotor has a relatively high retentivity, these poles will not tend to vary so quickly as would be the case if the rotor had a relatively low retentivity. Also, since the pole pieces have low retentivity, their strong magnetic poles easily become distorted or shifted to the solid N and S positions indicated in the pole pieces. Thus the highly retentive poles in the rotor tend to move with the rotor instead of being displaced therein.

Since the poles in the low retentive pole pieces tend respectively to follow the highly retentive moving poles in the rotor, each pair of poles consisting of an inducing and induced pole moves to a position wherein their mutual static attractions exert a very substantial torque around the center line of the shaft **9**. This torque reacts against the torque applied to the shaft **9**. At a very small angular displacement these torques will balance statically. It is to be noted that the north and south members of each pair of poles remain closer to one another than they would without flux shift in the pole pieces **3** and **5**. Hence their attractive actions remain high. It is also to be noted that each north and south rotor pole will, with a repulsive action, approach the next respective shifted north or south pole in the respective pole piece. This adds to the resistance set up against the applied torque. Consequently the static holding power of the device after a small angular displacement is very great.

The high retentivity in the rotor requires strong fields in the pole pieces to effect the desired polar conditions in the rotor, and that is one reason for employing the highly permeable soft iron pole pieces, which have a high induction constant. In such pole pieces, strong, but readily shiftable poles can be maintained for their inductive and attractive effect upon the rotor.

The attraction between pairs of inducing and induced poles is so great in apparatus when built as described, that a static resisting torque to applied torque, without slip, has been attained exceeding 1 lb. inch torque per square inch of rotor surface. This was in the case of a machine having a rotor only $\frac{9}{16}$ inch long and only $\frac{11}{16}$ inch in diameter with a $\frac{1}{32}$ inch air gap between the rotor and the pole pieces.

Any reduction of the applied static torque results in the rotor returning to its initial position, all energy stored in the flux field tensions being returned as mechanical work. This energy storing feature may be used to eliminate backlash in reeling mechanisms, as will appear.

The above-described static reacting torque is independent of angular velocity and depends upon angular displacement only, as indicated at the left in Fig. 4. Time is not important. From a starting position S the torque increases suddenly within an initial angular displacement of the order of 15° or so, which is independent of angular velocity. In Fig. 4 this relationship is plotted on the left side of the zero vertical ordinate. In the drawing, "Static initial angular displacement" along line S—O refers to that displacement which occurs with torque reaction but without the necessity for any appreciable angular velocity to bring about such reaction. As soon as the applied torque which is indicated over O in Fig. 4 is exceeded, slip sets in, which is to say that a condition of relative angular velocity comes into existence between the rotor **11** and the pole pieces **3** and **5**.

Assuming the rotor **11** to be formed of "Alnico," or laminated, both of which inhibit eddy-current losses, the torque will remain substantially constant at any angular velocity except for a very slight rise that is due (1) to small amounts of eddy currents that flow even in laminated or like structures and (2) to hysteresis losses. Deviations from constancy of torque under slip conditions depend primarily upon the eddy currents, provided they are allowed to flow in the rotor. As stated, "Alnico" inherently inhibits eddy currents. If the rotor is composed of chilled cast iron or the like, eddy currents will be inhibited by laminating it and torque constancy approached. If eddy currents are not inhibited, the torque curve will rise more steeply with increased angular velocity. In Fig. 4 the slightly rising characteristic for torque with rising velocity or slip speed is shown to exist because, even with an "Alnico" or a laminated rotor, a few eddy currents will appear and some hysteresis loss occurs.

If "Alnico" metal is used for the rotor, lamination need not be resorted to for reducing eddy currents because this material during the sintering process used for its manufacture evolves an inherently high internal resistance to the flow of eddy currents.

It is to be understood that even if torque builds up with speed, as when eddy currents are permitted to flow, neverthless there is still retained a sudden rise in torque (with angular displacement from an initial reference position) which is independent of angular velocity up to a certain

point, as indicated over S—O in Fig. 4. The only difference therefore between a solid rotor and a laminated or the equivalent rotor is that in the solid-rotor case eddy currents are generated and reacting torque increased to a certain extent with increased speed, but in the case of a laminated rotor or the equivalent, this is not true. The reacting torque increase will be hardly noticeable with thin laminations and increases with speed as the lamination thickness increases. However, an important point to be kept in mind is the structure which produces substantial reacting torque independently of speed, that is to say, the part of the action indicated in Fig. 4 above line S—O. Under conditions of substantial angular velocity a substantially rising torque depends primarily upon the production of eddy currents.

It will be understood that if up to the zero ordinate in Fig. 4 the moment applied to the rotor be reduced, the rotor will move toward its initial position and upon removal of all torque it will substantially reach that position. This is because internal losses under non-slip conditions are almost nil.

In Figs. 5 and 6 is shown a construction wherein both the field and the inductor members are made rotary and wherein instead of a permanent magnet an electrical coil is used for magnetization. In this case, pedestals 19 support a rotary shaft 21 which carries a cylindric rotor 23, the latter in this case being shown laminated and composed, for example, of chilled cast iron. Rotary on the shaft 21 are end bells 25 of a field member. These end bells are preferably non-magnetic and are fastened to a magnetic ring 27 having pole pieces 29. Wound upon the pole pieces are field coils 31 which are fed with direct current from a source of current 32 through slip rings 33. At 35 is shown a rheostat for controlling the flow of current through the coils 31 and hence the intensity of the flux fields emanating from the pole pieces 29. It is to be understood that the pole pieces 29 are again composed of material similar to that of the pole pieces of Fig. 1 and that the coils are wound to produce opposite N and S polarities in these poles. If one or the other of the relatively rotary members of Figs. 5 or 6 is caused to function as a rotary driving member, a reacting torque will be engendered. If the resisting torque on the driven member is equal to or less than the torque at which slip will occur, the driven member may be driven by means of the driving member without slip. After this torque is exceeded, slip occurs. This construction may be used as a coupling for clutch or dynamometer constructions. It will be seen that if the driven member is operating an item such as a winding and tensioning spool, when the driving action stops, any strand being tensioned by the spool will remain in tension provided the driving member is not retracted from the position in which it stops. Thus Figs. 5 and 6 show how the invention may be applied to apparatus in which a slip coupling is desired having the characteristics above specified.

In Figs. 7 and 8 is shown another form of the invention similar to that shown in Figs. 5 and 6, except that the rotor is in the form of a non-laminated disc made, for example, of chilled cast iron, and the field members present unlike magnetic poles on opposite sides of the disc. According to these Figs. 7 and 8, numeral 37 indicates the support for gudgeons 39 of a rotary field supporting frame 41. Within this frame 41 is a

rotary shaft 43 on which is the inductive rotor 45. The member 41 carries two C-shaped pole pieces 46 on the legs of which are windings 47 producing north and south poles at 49 and 51, respectively. The pole pieces at 49 and 51, are, for example, made of soft iron. Current is fed to the coils 47 through slip rings 53 from a source of current 54 and via a controlling rheostat 55. The action is the same as in Figs. 5 and 6 except that in this case the torque-producing attractive action between the poles of pole pieces 49 or 51 on the one hand, and the resulting induced poles in the rotor 45 is tangential to the sides of the disc.

In Figs. 9–12 is shown an application of the invention to a reel. Referring to these Figs. 9–12, numeral 57 indicates the non-magnetic frame of the reel in which is the rotary reel 59 for the line. The strand to be reeled is not shown. The reel is mounted upon a rotary shaft 61 on which is carried an "Alnico" or like cylindric rotor 63 made according to the above principles. Fastened in the end of the frame is a pair of soft iron pole pieces 65, which envelope the rotor over a substantial portion of the periphery; or as shown, more than half the peripheral surface of the rotor. Between the pole pieces is an "Alnico" permanent bar magnet 67 which magnetizes the pole pieces 65 to opposite polarities. On the frame 57 is a non-magnetic rotary cover 69 having circular guide slots 71. One of the slots 71 cooperates with a headed pin 73 and the other with a headed screw 75. By loosening the screw 75 and turning the cover 69 it may be adjusted to various angular positions. Within a recess in the cover is solidly positioned a magnetically permeable bar 77 which, due to the adjustable characteristics of the cover 69, may be set anywhere between either of two right-angular positions, such as indicated by the solid and dotted lines in Fig. 12. Thus the magnetic circuit of the bar magnet 67 which ordinarily passes through the pole pieces 65 and through the rotor 63 may be short-circuited in part so as to modify the magnetic strengths of the pole pieces 65.

When a strand on the reel pays out, it will spin the reel 59, which in turn spins the rotor 63. A magnetic braking action occurs between the rotor and the pole pieces 65. As illustrated in Fig. 4, the resisting torque immediately builds up to a certain value. This occurs during the first few degrees of movement of the rotor 63. This resisting torque is not substantially exceeded, even at high angular velocities of the reel and rotor. This means that the strand on the reel pays off with correct constant braking action, as determined by adjustment of the bar 77. The predetermined braking action is still effective up to the last degree of movement, preventing the occurrence of slack or backlash in the strand. In other words, the reel 59 does not overrun and tend to snarl the strand. This is due to the backlash take-up effect of the existing reactive torque at the final position (zero speed) of the rotor 63.

The above is only one example of many applications in which slack or backlash may effectively be kept out of material being paid from or to a reel or the like at the end of a reeling operation, and without having excessive braking action built up during said reeling operation.

From the above it will be seen that there is also provided means for constructing an electromagnetic coupling in which there is no loss of energy if the load does not exceed the static

holding power of the coupling because under such static holding conditions there is no slip.

In the application of the invention to a continuously operating electric slip clutch, there might be some loss of energy in the coupling during the time that a load is picked up; that is, slip might occur under the larger torque conditions required for accelerating the load, but after the acceleration is completed the lighter running torque may often be carried under the non-slip conditions between driving and driven members without loss of energy in the coupling.

In the above disclosure certain explanations have been made of the functioning of my invention. This has been for the purpose of explaining, so far as I am able, the improved results obtained by my new apparatus. It is to be understood, however, that the results obtained do not depend upon such explanations and they are offered only in the interest of producing a disclosure which is as clear as I am able to make it. It is of course clear that other and possibly better explanations do not affect the physical character of the improvement.

In connection with possible alternative explanations, it may be observed that in the case of rotor materials having high retentivity and high remanence there is usually associated a hysteresis loop of substantial area. The existence of such a loop may help to explain the operation. Thus, in the case of apparatus in which eddy currents have been inhibited in the rotor by the use of "Alnico," or laminations, any rising characteristic of the torque curve in Fig. 4 beyond point O may in part be due to hysteresis losses. I have observed that the maximum torque available depends upon the shape of the hysteresis loop and the area covered by it, and that maximum torque is obtained when the field strength is sufficient to operate the rotor just inside the hysteresis loop. This is no doubt due to the fact that hysteresis losses in a given material cannot be extended beyond those that are measured by the area of the loop, and since this area is predetermined for each material, it is a measure of the torque limit, ignoring eddy-current losses.

It should be noted in this connection that the means for adjusting the flux through the inductor, as shown in Figs. 1, 2, and 9–12, provide means for operating at maximum torque reaction when desired, under any conditions of operation to which the apparatus may be subjected. This maximum does not necessarily occur at maximum field strength, according to my tests.

The action of the present invention should not be confused with that of constructions which employ two relatively rotary permanently polarized members, or those in which the equivalent of so-called squirrel-cage constructions is used. In the case of apparatus employing two relatively movable polar members, any torque built up under static conditions cannot be maintained under slip conditions because under the slip conditions the opposite poles break away from one another and there is a tendency to drop the torque load entirely. That is not true of the present invention. Squirrel-cage and similar constructions may operate under slip conditions, but will not operate satisfactorily under static torque conditions, being more like, although not the same as, former homogeneous inductors which employed the eddy currents for transmitting torques under slip conditions only.

For the purpose of this specification, the term remanence is defined as the magnetic induction

which remains in a material after the removal of an applied magnetomotive force. Retentivity is the property of the material which is measured by the residual induction therein corresponding to its saturation induction. Permeability is the property of a material which determines, under given conditions, the magnitude relation between magnetic induction and magnetizing force in the material. These definitions correspond to those given in "American Standard Definitions of Electrical Terms," published by The American Institute of Electrical Engineers, approved 1941.

The term torque coupling as used herein refers to either a clutch or brake.

Although the pole pieces in the above description of Figs. 1, 2, 5, 6, 9 and 11 are shown as being outside of the relatively uninterrupted interior inductor, it will be understood that this relationship may be reversed without change in principle.

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

As many changes 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.

I claim:

1. A substantially constant-torque slip coupling comprising relatively rotary magnetic field and magnetic inductor members, said field member having spaced pole pieces of relatively low retentivity high-permeability magnetic material in magnetic inductive relation to the inductor member, the inductor member having a sweep surface which is relatively uninterrupted with respect to the spaced pole pieces and being polarized primarily by the pole pieces, said inductor member being constructed of magnetic material having characteristics of high hysteresis-loss, and means for producing non-alternating poles in said pole pieces comprising a permanent magnet.

2. A substantially constant-torque slip coupling as set forth in claim 1 further including an adjustably positionable member of magnetic material which is movable toward and away from the pole pieces for adjustably by-passing portions of the flux at the pole pieces.

3. A substantially constant-torque magnetic tensioning brake comprising a rotor and a stator, the stator having a polarized permanent magnet of high-retentivity magnetic material and pole pieces of low-retentivity magnetic material at the polar ends of the magnet, the rotor having a smooth annular sweep surface adjacent the pole pieces and being formed of eddy-current inhibiting and high-hysteresis-loss magnetic material, the rotor being polarized solely by the pole pieces.

4. In a pay-off reel, a magnetic inductor member driven by the reel and a magnetic field member secured to the frame of the reel, the field member having a polarized permanent magnet of high-retentivity magnetic material and pole pieces of low-retentivity magnetic material at the polar ends of the magnet, the inductor member having a smooth annular sweep surface adjacent the pole pieces formed of eddy-current inhibiting high-hysteresis-loss magnetic material and polarized solely by the pole pieces.

5. A slip coupling having a high torque at

low speed comprising relatively rotary magnetic field and magnetic inductor members, the inductor member being in the shape of a cylinder and being composed of high-hysteresis-loss magnetic material at least at the periphery thereof, the field member having pole pieces of low-retentivity high-permeability magnetic material enveloping the inductor over a substantial portion of its periphery, and means for producing a non-alternating field in said pole pieces comprising a permanent magnet, the inductor being polarized only by the pole pieces.

ANTHONY WINTHER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
396,602	Rice	Jan. 22, 1889
1,308,435	Maire	July 1, 1919
1,424,769	Morrison	Aug. 8, 1922
1,531,389	Gordon	Mar. 31, 1925
1,546,269	Warren	July 14, 1925
1,665,613	Tanner	Apr. 10, 1928
2,056,177	Erbguth	Oct. 6, 1936
2,070,447	Morrill	Feb. 9, 1937
2,183,404	Morrill	Dec. 12, 1939
2,241,983	Connolly	May 13, 1941
2,373,609	Stahl	Apr. 10, 1945
2,386,505	Puchy	Oct. 9, 1945
2,390,877	Fisher	Dec. 11, 1945

FOREIGN PATENTS

Number	Country	Date
458,671	Great Britain	Dec. 18, 1936

OTHER REFERENCES

"Experimental Electrical Engineering," Karapetoff, vol. 1, second edition, published in 1910 by John Wiley and Sons, New York city, pages 190 to 195.