

Sept. 30, 1969

TOSHIYA MURATA ET AL

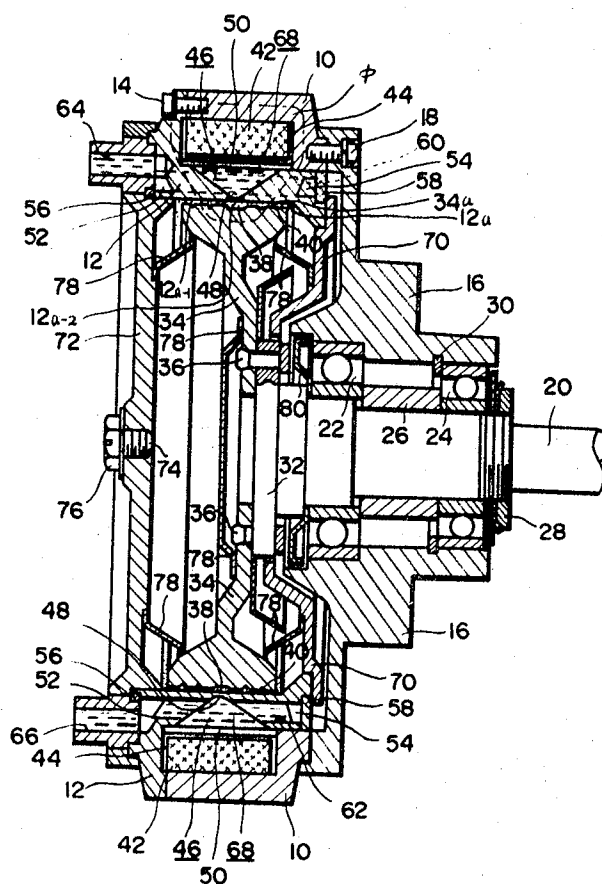
3,469,665

ELECTROMAGNETIC CONNECTOR

Filed Aug. 27, 1967

2 Sheets-Sheet 1

Fig. 1.



Sept. 30, 1969

TOSHIYA MURATA ET AL

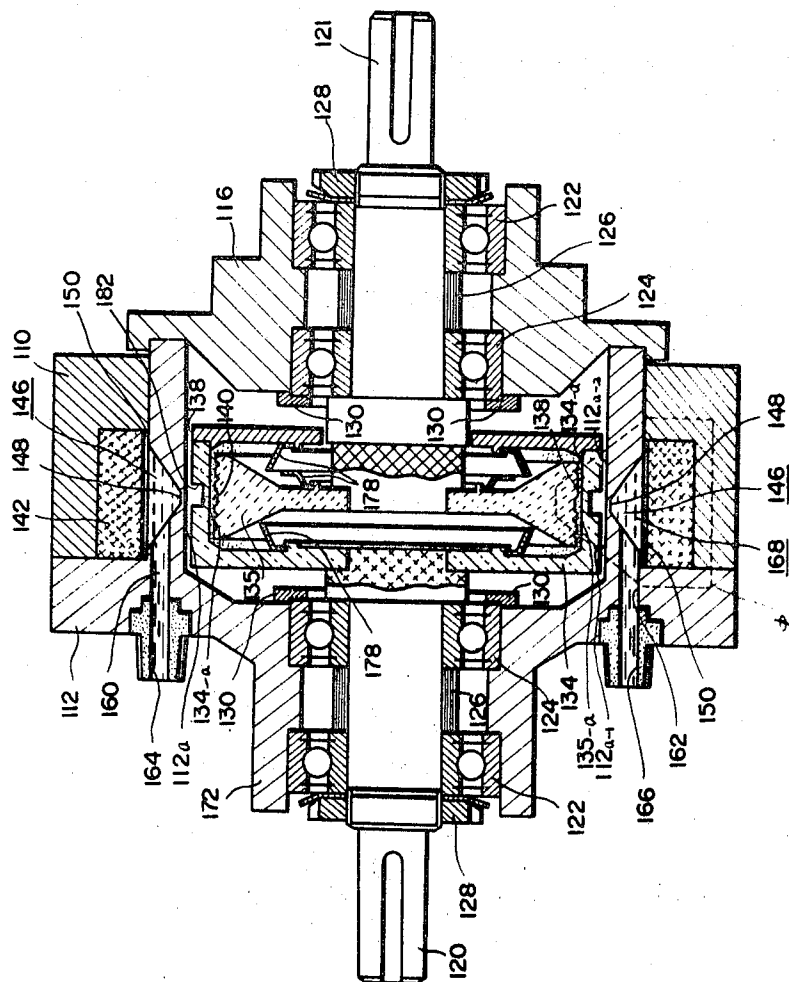
3,469,665

ELECTROMAGNETIC CONNECTOR

Filed Aug. 22, 1967

2 Sheets-Sheet 2

Fig. 2.



1

3,469,665

ELECTROMAGNETIC CONNECTOR

Toshiya Murata, Toshiyuki Takahashi, and Yoshiharu Kobayashi, Himeji, Japan, assignors to Mitsubishi Denki Kabushiki Kaisha, Tokyo, Japan

Filed Aug. 22, 1967, Ser. No. 662,453

Int. Cl. F16d 27/02, 13/74, 65/78

U.S. Cl. 192—21.5

5 Claims

ABSTRACT OF THE DISCLOSURE

In electromagnetic brake, a stator including an electromagnetic winding in it is provided on that portion facing a rotor with a space to magnetically divide the stator surface into two surface portions. A magnetic flux from the electromagnetic winding forcedly flows from the stator through one of the surface portions into a gap between the stator and rotor and then through the other surface portion back to the stator ensuring that magnetic particles in the gap are agglomerated into a rigid body to firmly connect the rotor to the stator. In electromagnetic clutches, a housing surrounding two clutch flanges is provided with an electromagnetic winding and a space similar to those in the brake to force a magnetic flux to flow through a gap between the two clutch flanges. In either case, a coolant circulates through the space.

This invention relates in general to an electromagnetic connection apparatus for magnetically connecting a pair of relatively rotary connector members to establish a mechanically bonding force therebetween, and more particularly to an electromagnetic connection apparatus of the type in which magnetic particles interposed between a pair of main connector members are magnetized into an agglomeration to exert a mechanically bonding force on the main connector members.

In operation the conventional type of electromagnetic connection apparatus referred to has generally heat generated by the magnetic particles and main connector members due to frictions therebetween. The heat thus produced will then oxidize the magnetic particles to deteriorate their magnetic characteristics. Further such heat may fuse a great part of the magnetic particles to each other and sometimes to the main connector members to decrease the fluidity of the magnetic particles. This makes it difficult to control the agglomeration of the magnetic particles by controlling a magnetic flux flowing through the latter.

Accordingly it is an object of the invention to provide a new and improved electromagnetic connection apparatus including cooling means for sufficiently removing the said heat while the apparatus is maintained relatively small-sized.

A more special object of the invention is to provide a new and improved electromagnetic brake apparatus relative small in size and reliable in operation with excessive heating effectively prevented.

Another more special object of the invention is to provide a new and improved electromagnetic clutch apparatus relative small in size and reliable in operation with excessive heating effectively prevented.

Briefly, the invention accomplishes the above cited objects by the provision of an electromagnetic connection apparatus comprising a pair of relatively rotatable main connector members of ferromagnetic material disposed in opposed relationship to form a gap therebetween, an amount of magnetic particles filling the gap, an electromagnetic winding disposed in a ferromagnetic stationary part of the apparatus and capable of being electrically energized, the electromagnetic winding, when energized,

2

producing a magnetic flux to agglomerate said magnetic particles into a substantially rigid body thereby to establish a bonding force on the pair of main connector members, a space formed the stationary part to magnetically divide the surface through which the flux flows of the stationary part into a pair of surface portions, the magnetic flux forcedly flowing from the stationary part through one of the surface portions into the magnetic particles in said gap and thence through the other surface portion back to the stationary part, a coolant circulating through the space, and an introduction and an exhaust port disposed on the stationary part to flow said coolant therethrough.

In a preferred embodiment of the invention as applied to electromagnetic brakes, a stator member of ferromagnetic material in the form of a circular annulus may surround a disc-shaped rotor member of ferromagnetic material to form an annular gap therebetween with magnetic particles filling the gap. The stator member has an electromagnetic winding disposed therein and an annular space of triangular cross section disposed between the winding and the internal peripheral surface of the stator member to magnetically divide that surface into a pair of surface portions whereby a magnetic flux from the electromagnetic winding is forced to flow from the stator member through one of the surface portions into the annular gap and thence through the other surface portion back to the stator member. An introduction and an exhaust outlet port are disposed on the stator member to circulate a coolant to the annular space therethrough.

In a preferred embodiment of the invention as applied to electromagnetic clutches, a housing member of ferromagnetic material in the form of a circular annulus may surround a cup-shaped rotor member of ferromagnetic material and a disc-shaped rotor member of ferromagnetic material disposed in opposed coaxial relationship within the cup-shaped rotor member to form an annular gap between both rotor members with magnetic particles filling the gap. The housing member has an electromagnetic winding disposed therein and an annular space of triangular cross section disposed between the winding and the internal peripheral surface of the housing member to magnetically divide that surface into a pair of surface portions whereby a magnetic flux is forced to flow from the housing member through one of the surface portions and the cup-shaped rotor member into the annular gap and thence the cup-shaped rotor member back to the housing member. An introduction and an exhaust port are disposed on the housing member to circulate a coolant to the annular gap therethrough.

The invention as to its organization and its mode of operation as well as other objects and advantages thereof will be best understood from the following detailed description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a sectional view of an electromagnetic brake apparatus constructed in accordance with the principles of the invention; and

FIGURE 2 is a sectional view of an electromagnetic clutch apparatus constructed in accordance with the principles of the invention.

While the invention is applicable to a wide variety of electromagnetic connection apparatus the same is particularly suitable for use in electromagnetic brakes and clutches and therefore will be illustrated and described in terms of such brake and clutch.

Referring now to FIGURE 1 of the drawings, there is illustrated an electromagnetic brake apparatus constructed in accordance with principles of the invention. An arrangement illustrated comprises an outer stationary housing member 10 of ferromagnetic material such as mild steel and an inner stationary housing member 12 of ferro-

magnetic material rigidly secured thereto through bolts 14 only one of which is shown. The outer housing member 10 is a hollow cylindrical configuration with an L-shaped cross section while the inner housing member 12 is also of a hollow cylindrical configuration but has an inverted L-shaped cross section. Thus both housing members connected together has an annular space formed between their arms of the L's for the purpose as will be apparent hereinafter. Both stationary members and particularly the inner housing member 12 provide a first main connector member of the apparatus.

The arrangement further comprises a cover member 16 rigidly secured to the outer housing member 10 through bolts 18 (only one of which is shown) and a partially threaded rotary shaft 20 centrally extending through the cover member 16 and rotatably supported to the latter by means of a pair of ball bearings 22 and 24. The shaft 20 has a tubular spacer 26 fitted onto it between the ball bearings 22 and 24 the inner races of which are fixed on the shaft 20 by fastening nut 28 screwed onto the latter. The outer bearing 22 is put in place by having a snap ring 30 engaging a peripheral groove formed on the central bore wall of the cover member 16.

The rotary shaft 20 is provided on that end adjacent the inner ball bearing 24 which a flange 32 having a disc-shaped rotor member 34 of ferromagnetic material disposed coaxial to the housing members 10 and 12 and fixed thereto through rivets 36. The disc-shaped rotor member 34 has a longitudinally enlarged peripheral portion whose outer peripheral surface provides a braking surface 34a facing the internal peripheral or braking surface 12a of the inner stator member 12 with a narrow annular gap 38 formed therebetween. The rotor member 34 provides a second main connector member and preferably includes a plurality of peripheral grooves as shown on the braking surface 34a for the purpose of increasing on braking action as will be described hereinafter. The annular gap 38 is filled with an amount of magnetic particles 40 such as powdered iron and the above-mentioned annular space formed between both housing members 10 and 12 has disposed therein an electromagnetic winding 42. The winding 42 is put in place by having spacers 44, 44 of any suitable non-magnetic material such as aluminium disposed on the both end faces and internal peripheral face thereof.

According to the principles of the invention, an annular space 46 of triangular configuration is formed in the arm of the L of the inner stator member 12 with the base of the triangle facing the electromagnetic winding 42 while the apex of the triangle extends toward the braking surface 12a of the stator 12 to form a central reduced portion 48 having an extremely high reluctance in the L's arm of the inner stator 12 thereby to magnetically divide the braking surface 12a into two surface portions 12a-1 and 12a-2. The base of the triangle 46 is closed by a sealing member 50 of any suitable non-magnetic material such as copper in the form of a hollow cylinder welded to the internal peripheral surface of the stator member 12.

The inner stator member 12 is provided on both end faces of its L's arm with a pair of annular grooves 52 and 54 the open sides of which are closed by sealing rings 56 and 58 welded to both end faces of the L's arms of the stator 12. The inner stator member 12 further is provided on the arm of the L with a pair of axial connecting openings 60 and 62 communicating with annular space 46 and the annular grooves 52 and 54.

In order to circulate a coolant such as water, oil or gaseous medium through the triangular groove 46, an introduction and an exhaust port 64 and 66 respectively are disposed on the lefthand end face as viewed in FIGURE 1 of the inner stator member 12 and communicates with the connecting openings 60 and 62 respectively. Thus the coolant designated by the reference numeral 68 will flow from a reservoir (not shown) through the introduction port 64, the axial opening 60, the annular groove 52, the annular

space 46, the annular groove 54, the axial opening 62 and the exhaust port 66 and back to the reservoir.

Disposed between the cover member 16 and the rotor member 34 is a stationary aluminum plate 70 having its outer periphery fixed to the righthand end portion as viewed in FIGURE 1 of the internal periphery of the stator member 12 and its inner periphery opposing the flange 32. A cover 72 is rigidly secured to that end portion of the inner stator 12 arm on which the inlet and outlet ports 64 and 66 are disposed, or the lefthand end portion thereof as viewed in FIGURE 1 and provided on the center with a threaded hole 74 for injecting the magnetic particles 40 in the gap 38, the hole being normally closed by a bolt 76. A plurality of labyrinthine seals 78, 78 of any suitable non-magnetic material such as brass or stainless steel are disposed between the stationary plate 70 and the rotor member 34 and between the cover 72 and the rotor member 34 in order to prevent the magnetic particles 40 from escaping from the gap 38. Also an oil seal 80 is disposed on the ball bearing 22 to prevent oil in the bearings 22 and 24 from entering the gap 38.

With the rotor member 34 rotating, a source of electric power (not shown) can energize the electromagnetic winding 42 to impart a braking torque to the rotor member 34. More specifically, when the electromagnetic winding 42 is energized, a magnetic flux is produced in the material for the outer and inner stator members 10 and 12. It is here recalled that the inner stator member 12 has disposed adjacent the braking surface 12a the central reduced portion extremely high in reluctance to magnetically divide that surface into two surface portions 12a-1 and 12a-2. Therefore, as shown at broke line ϕ in FIGURE 1, the flux if forced to flow the arm of the L of the inner stator member 12 through one of the braking surface portions and the magnetic particles 40 in the annular gap 38 into the rotor member 34 and thence through the magnetic particles and the other braking surface portion back to the inner stator member. This ensures that the magnetic particles 40 within the annular gap 38 are agglomerated into a substantial rigid body with the result that the stator member 12 is connected to the rotor member 34 to apply a braking torque to the latter. This braking torque has a magnitude proportional to a degree to which the magnetic particles have been agglomerated which degree is, in turn, proportional to a magnitude of current flowing through the electromagnetic winding 42. Thus it will be appreciated that the magnitude of braking torque can be controlled by adjusting the magnitude of current flowing through the electromagnetic winding 42.

As the spacers 44, 44 associated with the winding 42 and the sealing plate 50 are made of any suitable non-magnetic material they never short out the magnetic flux flowing through the material for the inner stator member 12 and the magnetic particles 40 in the gap 38.

It will be readily understood that with the braking torque applied to the rotor member 34 in the manner as above described, any sliding movement of the same relative to the agglomerated magnetic materials 40 produces a large quantity of heat on the braking surfaces of both stator and rotor members 12 and 34, proportional to a product of the number of revolution per unit time of the rotor member multiplied by the magnitude of braking torque. Thus if the number of revolutions and/or the braking torque are or is high the quantity of heat produced will become significantly large.

The invention contemplates to prevent the braking surfaces of the stator and rotor members 12 and 32 from being excessively heated. To this end, the coolant 68 is caused to circulate through the annular space 46 and the annular grooves 52 and 54 effectively to carry out heat generated on the braking surfaces. The coolant circulates from its reservoir (not shown) through the introduction port 64, the annular groove 52, the connecting opening 60 to the space 46 and thence through the connecting opening 62, the annular groove 54, the exhaust port 66 and back to reservoir.

Referring now to FIGURE 2 wherein the same reference numerals greater by 100 designate the components corresponding or similar to those shown in FIGURE 1, there is illustrated an electromagnetic clutch apparatus embodying the principles of the invention. A housing assembly comprising an outer and an inner housing member 110 and 112 respectively of any suitable ferromagnetic connected together forms closed space together with a pair of opposed cover members 116 and 172. The housing members 110 and 112 are substantially similar in construction to the housing members 10 and 12 while both cover members are also substantially similar in construction to the cover member 16. A pair of axially aligned shafts 120 and 121 rotatably extend through the respective covers 116 and 172 into the said closed space in the same manner as previously described in conjunction with FIGURE 1, and have at their opposed ends a pair of opposed flanges 134 and 135 of any suitable ferromagnetic material.

More specifically the rotary shaft 120 has rigidly secured at its inner end a flange 134 of cylindrical cup shape while the rotary shaft 121 has rigidly secured at its inner end a flange 135 similar in shape to the rotor member 34 as previously described and disposed within the cup of the flange 134 with a narrow annular gap 138 formed between the inner peripheral wall of the flange 134 and the outer peripheral wall of the flange 135. The outer peripheral wall of the cup 134 is provided midway the length or on that portion facing a reduced portion 148 on the inner housing member 112 with an annular groove 182 preferably having a rectangular cross section ensuring that the groove 182 cooperates with the reduced housing portion 112 to force a magnetic flux from an electromagnetic winding 42 to enter the magnetic particles 140 within the annular gap 138 to rigidly connect both flanges and therefore both rotary shafts 120 and 121 to each other through agglomeration of the magnetic particles 140 by their magnetization. An introduction and exhaust passages 164 and 166 respectively are disposed in the inner housing member 112 to be directly connected to the annular gap 138. In other respects the arrangement shown in FIGURE 2 is substantially identical to that illustrated in FIGURE 1.

Thus it will be appreciated that with the electromagnetic winding 142 energized by a source of electric power (not shown) magnetic particles 140 filling the annular gap 138 are agglomerated into a substantially rigid body to connect both flanges 134 and 135 and therefore both shafts 120 and 121 to each other to permit rotation of one of the shafts to be transmitted to the other shaft. On the other hand, when the electromagnetic winding is de-energized, one of the shafts is allowed to be freely rotated with respect to the other shaft with the results no rotational movement is not transmitted from one to the other of the shafts.

If either of the electromagnetic brake and clutch apparatus as previously described includes no cooling means and is required to dissipate heat generated on the braking or clutching surfaces through self-cooling then the high number of revolution of the rotor or of sliding rotation thereof and/or a high braking torque or a high transmission torque as the case may be inevitably leads to excessive heating of the braking or clutching surfaces, particularly when the apparatus is small-sized. This causes the magnetic particles to oxidize to deteriorate their magnetic characteristics. Alternatively a great part of the magnetic particles is fused to each other and further to the braking or clutching surfaces resulting in significant deterioration of the braking or torque transmission characteristics. This is a serious obstacle to miniaturization of the apparatus and an increase in number of revolution of the rotor and an increase in braking torque for brake or to an increase in transmission torque for the clutch. From the foregoing, however, it will be appreciated that the invention effectively eliminates such an obstacle by the provision of a

cooling space in the inner stationary housing member.

In summary, the invention is characterized by the annular space disposed in the inner housing member to force substantially all the magnetic flux from the electromagnetic winding to flow through the annular space 46 or 146 as well as a coolant 68 or 168 circulates through the said annular space to remove away heat generated on the braking or clutching surfaces. This measure eliminates the necessity of disposing a separate cooling space through which a coolant circulates, and permits the braking or clutching surfaces to be sufficiently cooled without the necessity of making the apparatus large-sized.

The provision of the cooling spaced 46 or 146 in the stationary housing ensures that this space is completely closed as by the sealing copper ring 50 or 150 welded to the housing. This avoids a fear that the coolant may leak from the cooling space to damage the electromagnetic winding 42 or 142, the magnetic particles 40 or 140 etc. Also the coolant can reliably enter and discharge from the cooling space 46 or 146 with a simple construction.

If the brake apparatus for the invention has a relatively large quantity of heat generated on the braking surfaces it is required to use the annular grooves 52 and 54 for cooling purpose. However it is generally required only to utilize the annular space 46 for the same surface. In the latter case, a sufficient cooling can be accomplished by properly selecting the type of the coolant, its flow rate, the dimension of the space, etc.

The invention has several advantages. For example, electromagnetic connection apparatus and more particularly electromagnetic brake and clutch apparatus can be sufficiently cooled in operation and increase their durability and thermal capability without the apparatus rendered large-sized. While the invention has been illustrated and described in conjunction with only two preferred embodiments thereof it is to be understood that various changes and modifications may be resorted to without departing from the spirit and scope of the invention.

What we claim is:

1. An electromagnetic connection apparatus comprising a pair of relatively rotatable main connector members of ferromagnetic material disposed in opposed relationship to form a gap therebetween, an amount of magnetic particles filling said gap, an electromagnetic winding disposed in a ferromagnetic stationary part of the apparatus and capable of being electrically energized, said electromagnetic winding, when energized, producing a magnetic flux to agglomerate said magnetic particles into a substantially rigid body thereby to establish a bonding force on said pair of main connector members, means defining a closed space in said stationary part to divide the surface through which said flux flows of said stationary part into a pair of magnetic surface portions, said space being disposed circumferentially of said surface portions and adjacent thereto said magnetic flux flowing in operation from said stationary part through one of said surface portions into said magnetic particles in said gap and through the other surface portion back to said stationary part, a coolant circulating through said space in contact with said pair of surface portions, and an inlet and an exhaust port disposed on said stationary part to flow said coolant therethrough.

2. An electromagnetic connection apparatus for use as an electromagnetic brake, comprising a main stationary connector member and a main rotatable connector member disposed on opposed relationship to form a gap therebetween, both said main connector members being composed of a ferromagnetic material, an amount of magnetic particles filling said gap, an electromagnetic winding disposed in said stationary connector member, to surround said gap and capable of being electrically energized, said electromagnetic winding, when energized, producing a magnetic flux to agglomerate said magnetic particles into a substantially rigid body to impart a braking torque to

said rotatable connector member, means defining a closed space disposed in said stationary connector member between said electromagnetic winding and that surface facing said rotatable connector member of said stationary member to divide said stationary into a pair of magnetic surface portions, said space being disposed circumferentially of said surface portions and adjacent thereto said magnetic flux flowing in operation from said stationary connector member through one of said stationary surface portions into said magnetic particles in said gap and through the other surface portion back to said stationary connector member, a coolant circulating through said space in contact with said surface portions, and an introduction and an exhaust port to flow said coolant there-through.

3. An electromagnetic connection apparatus as claimed in claim 2, wherein said main stationary connector member is in the form of a circular annulus and has rotatably disposed therein said rotatable connector member to form an annular gap between the internal peripheral surface of said stationary connector member and the externally peripheral surface of said rotatable connector member, with an amount of magnetic particles filling said annular gap.

4. An electromagnetic connection apparatus for use as an electromagnetic clutch, comprising a pair of main rotatable connector member of ferromagnetic material disposed in opposed coaxial relationship to form a gap therebetween, a stationary housing member of ferromagnetic material disposed adjacent said pair of main rotatable connector member, an amount of magnetic particles filling said gap, an electromagnetic winding disposed in said housing member, to surround said gap and capable of being electrically energized, said electromagnetic winding, when energized, producing a magnetic flux to agglomerate said magnetic particles into a substantially rigid body to transmit a torque from one of said rotatable con-

connector member to the other, means defining a closed space disposed in said housing member between said electromagnetic winding and the internal peripheral surface of the housing member to divide said surface into a pair of magnetic surface portions, said magnetic flux flowing in operation through said housing member through one of said housing surface portions into said magnetic particles in said gap and through the other housing surface portion back to said housing member, a coolant circulating through said space in contact with said surface portions, and an inlet and an exhaust port disposed on said housing member to flow said coolant therethrough.

5. An electromagnetic connection apparatus as claimed in claim 4, wherein said housing member is in the form of a circular annulus and has a cup-shaped main connector member rotatably disposed therein slightly spaced away therefrom and a disc-shaped main connector member rotatably disposed in opposed coaxial relationship within said cup-shaped connector member to form an annular gap between the peripheral surfaces of both connector means with an amount of magnetic particles filling said annular gap.

References Cited

UNITED STATES PATENTS

2,111,335	3/1938	Sanford	
2,575,360	11/1951	Rabinow	192—21.5
3,163,273	12/1964	Maier	192—21.5 X
3,262,534	7/1966	Monroe et al.	192—21.5 X
3,270,841	9/1966	Grau	192—21.5

DUANE A. REGER, Primary Examiner

U.S. Cl. X.R.

188—164, 264; 192—113