

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) BRUSHLESS DIRECT CURRENT MOTOR

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company, of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to brushless direct current motors which may be adapted for operation in connection with transistorized driving circuits.

Many forms of such direct current motors have been proposed but they all suffer from the disadvantages of not being self-starting and of failing to consistently rotate the rotor thereof in a predetermined direction.

One proposed approach to overcome these difficulties is the provision of a Hall-effect sensing element but the cost of such elements is extremely high.

This invention seeks to provide a brushless direct current motor which can be readily assembled and disassembled, which is self-starting, always rotates in the predetermined direction, and is of extremely simple construction and relatively low cost.

According to the present invention, there is provided a direct current brushless motor including a rotor shaft, a pair of spaced yokes mounted on said shaft for rotation therewith, a plurality of pairs of permanent magnets radially arranged about said shaft between said yokes, the magnets of each of a given pair of permanent magnets being mounted on a different yoke with a gap therebetween, three driving coils disposed in the gap between said pairs of permanent magnets, and a detecting means responsive to the position of said rotor shaft and having at least one detecting coil associated with each driving coil for the activation of said driving coil to rotate said rotor shaft, and a base of insulating material having said driving coils mounted thereon in angularly spaced relationship, said base being formed with a notch extending from one edge thereof to the centre of said driving coils and being adapted to receive said

rotor shaft during the operation of said motor and to permit the displacement of said rotor shaft therealong during assembly of the motor.

Preferably the poles of each pair of permanent magnets defining the gap therebetween are of opposite polarity to produce a magnetic field in said gap and the poles of adjacent permanent magnets on each of said yokes are of different polarity, said motor being provided with six pairs of permanent magnets circumferentially spaced about said rotor so that each of said pairs of permanent magnets substantially occupies a 60 degree sector, each of said driving coils substantially occupying a 60 degree sector and mounted on said base such that parts of one driving coil are angularly spaced from corresponding parts of each of the other driving coils by 100 degrees.

Said detecting means may include a shield ring formed from a conducting material and located between pairs of said detecting coils, said shield ring having cut-away portions in the path of said detecting coils to permit the operation of each detecting coil when said cut-away portions are aligned therewith for the activation of the driving coil associated with said detecting coil, said detecting coils being spaced circumferentially about the rotor shaft at 40 degree intervals, each of said cut-away portions defining a 40 degree circumferential arc about said rotor shaft.

Preferably said motor is provided with three pairs of detecting coils, said shield ring being provided with three cut-away regions equally spaced about said rotor shaft.

The invention will be described, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is an exploded perspective view of a brushless direct current motor according to the present invention,

Figure 2 shows an enlarged exploded view of the driving coils and permanent magnets of the motor of Figure 1,

[Price 5s. 0d. (25p)]

Figure 3 is a top plan view of the shield plate of the motor of Figure 1.

Figure 4 is a top plan view of the detecting coils of the motor according to Figure 1, and

Figure 5 is a block diagram showing the driving circuit for the motor of Figure 1.

Referring now to Figure 1, the direct current brushless motor shown is exploded along the axis of rotor shaft 1 thereof away from yoke 2. When assembled, a pair of yokes 2 and 3 are mounted on shaft 1 in spaced relation. Arranged radially about shaft 1 are permanent magnets 4 to 15, the magnets being arranged in two spaced apart radial planes such that pairs of magnets, e.g. 4 and 10, 5 and 11, 6 and 12, 7 and 13, 8 and 14, and 9 and 15, are axially aligned with each other. One of each of said pairs of magnets, namely magnets 4, 5, 6, 7, 8 and 9, are fixedly secured to yoke 2, while the others of said permanent magnets are fixedly secured to yoke 3, by means not shown. Each of said permanent magnets is substantially fan-shaped, defining a sector of an arc about shaft 1. Each of said pairs of permanent magnets is in spaced relation and disposed with opposite poles in facing relation. Thus, the south pole of magnet 7 faces the north pole of magnet 13. Further, the six poles secured to each yoke are disposed so that adjacent magnets have their opposite poles facing the air gap between said pairs of permanent magnets to produce a magnetic field in said gap. Thus, permanent magnet 4 has its north pole facing the air gap and its companion permanent magnet 10, while the adjacent permanent magnets 9 and 5 both have their south poles facing said air gap and their respective companion magnets. By this arrangement, the magnetic fields between pairs 4 and 10, 6 and 12 and 8 and 14 extend in the direction of arrow 50 while the magnetic fields between pairs 5 and 11, 7 and 13 and 9 and 15 extend in the direction of arrow 51.

Disposed in the air gap between said pairs of permanent magnets are substantially sector-shaped flat driving coils 17, 18 and 19. Said driving coils are radially arranged about rotor shaft 1 but are mounted independently thereof in apertures in a base 52 of insulating material as more particularly shown in Figure 2. The permanent magnets are circumferentially distributed about shaft 1 at equal intervals of 60 degrees, while the three driving coils 17, 18 and 19 are mounted on base 52 at a circumferential interval of 100 degrees between coils 17 and 18 and 18 and 19 about the shaft 1, so that the angle or interval between coils 19 and 17 is 160°. Further, the driving coils are arranged so that the angles defined between the centre lines of sides 38 and 39 of coil 17, sides 41 and 42 of coil 18 and sides 44

and 45 of coil 19 are all equal and are 60 degrees. Also as shown in Figure 2, base 52 is provided with a notch 53 extending from one edge thereof to the centre of said driving coils, said notch 53 being adapted to accommodate rotor shaft 1 during normal operation and for the insertion and removal thereof.

Also provided is a detecting means consisting of three pairs of detecting coils 25 and 26, 27 and 28, and 29 and 30, as more particularly shown in Figure 1 and Figure 4. The detecting coils are preferably formed in the shape of small discs with the detecting coils forming each pair being disposed in spaced relation with an air gap therebetween. The pairs of detecting coils are disposed radially about rotor shaft 1 with an angle of 40 degrees being defined between pairs 25 (26) and 27 (28), and 29 (30), respectively. The detecting means also includes a shield plate 31 as shown in Figures 1 and 3 fixedly mounted to rotor shaft 1 and extending into the gap between the pairs of detecting coils. The shield plate 31 is formed with three cut-away regions 32 within the path of detector coil air gaps. The cut-away regions 32 are spaced equally radially about rotor shaft 1, each of said openings defining a 40 degree arc. The shield plate 31 is preferably formed from a material of low electric resistance, such as aluminium.

Referring now to Figure 5, the driving circuits of the motor according to the invention are shown schematically. Each driving circuit consists of an oscillator 68, or 69 or 70, a demodulating circuit 71 or 72 or 73 for rectifying the output of the oscillators and a respective power amplifier 74, 75 and 76 for applying a driving current to the corresponding driving coils. One of the pairs of detecting coils is connected to each oscillator circuit to govern the oscillation thereof while a corresponding driving coil is connected to the output of the power amplifiers.

Referring now to Figures 1-4, the operation of the motor according to the invention is explained as follows. When the cut-away portion 32 of shield plate 31 is positioned opposite detecting coils 27 (28), the oscillator 69 connected to these coils commences oscillation. The oscillating wave is demodulated by demodulator 72, amplified by power amplifier 75 to apply driving current through driving coil 18. When the current flows through said driving coil in the direction of arrows 60 and 61 (Figure 2), the side 41 of said driving coil acts on the pair of permanent magnets 5 and 11, while the side 42 thereof acts on the pair of permanent magnets 6 and 12, to produce a force in the direction of arrow 57 in accordance with the normal laws of magnetic fields. Accordingly, the whole rotor assembly

including shield disc 31 rotates in the direction of said arrow 57.

When rotor shaft 1 has rotated about 40 degrees in the direction of arrow 57, shield plate 31 is interposed between the pair of detecting coils 27 and 28 to stop the oscillation of oscillator 69. During the above-described period, shield plate 31 was interposed between the other pairs of detecting coils to prevent the oscillation of oscillator 68 and 70. However, at the moment that oscillator 69 stops operation, cut-away region 32 is disposed opposite detecting coils 29 (30) causing oscillator 68 to commence operation to apply driving current to coil 19. When the current flows through driving coil 19 in the direction of arrows 58 and 59, the side 45 of said driving coil acts on the pair of permanent magnets 7 and 13 while the side 44 acts on the pair of permanent magnets 6 and 12 to apply a force to the rotor assembly to continue the rotation thereof in the direction of arrow 57. Of course, the rotation of shaft 1 carries with it yokes 2 and 3, the permanent magnets, and the shield plate 31. This portion of the cycle continues while the rotor rotates 40 degrees until shield plate 31 is interposed between detecting coils 29 (30) while cut-away region 32 is disposed opposite detecting coils 25 (26) to apply a driving current to driving coil 17. When the current flows through coil 17 in the direction of arrows 62 and 63, the side 39 of said coil acts on the pair of permanent magnets 8 and 14, while the side 38 acts on the pair of permanent magnets 9 and 14 to produce a continued rotative force in the direction of arrow 57.

The above-described cycle is repeated with every 120 degree rotation of the rotor shaft with the detecting coils and driving coils being sequentially activated to continuously rotate the rotor shaft in a predetermined direction.

Driving coils 17, 18 and 19 may be disposed in a variety of positions. Thus, the following chart represents some examples of the angular displacement at which driving coils 18 and 19 may be disposed relative to driving coil 17.

	Driving Coil 18	Driving Coil 19
	40 degrees	20 degrees
	100 "	80 "
55	160 "	140 "
	220 "	200 "
	280 "	260 "
	340 "	320 "

Of the foregoing arrangements, it has been found that by disposing the sector shaped permanent magnets of the rotor at intervals of 60 degrees, and the driving coils at intervals of 100 degrees, the rotor can self-

start from any rest position. The construction shown in the drawings, in which driving coil 18 is disposed at 100 degrees and driving coil 19 is disposed at 200 degrees relative to driving coil 17 is found to be preferred and is readily assembled and manufactured. This results from the fact that the driving coils are not stacked one upon another and that notch 53 can be provided in base 52 to permit the insertion and removal of rotor shaft 1.

In addition, there are a variety of arrangements for the detecting coils according to the invention but, by disposing said detecting coils at an interval of 40 degrees on one side of the device, a simple mounting arrangement may be provided.

By arranging the motor according to the invention in the preferred manner, a motor is produced which is inexpensive to produce and operate while being extremely compact.

WHAT WE CLAIM IS:—

1. A direct current brushless motor including a rotor shaft, a pair of spaced yokes mounted on said shaft for rotation therewith, a plurality of pairs of permanent magnets radially arranged about said shaft between said yokes, the magnets of each of a given pair of permanent magnets being mounted on a different yoke with a gap there-between, three driving coils disposed in the gap between said pairs of permanent magnets, and a detecting means responsive to the position of said rotor shaft and having at least one detecting coil associated with each driving coil for the activation of said driving coil to rotate said rotor shaft, and a base of insulating material having said driving coils mounted thereon in angularly spaced relationship, said base being formed with a notch extending from one edge thereof to the centre of said driving coils and being adapted to receive said rotor shaft during the operation of said motor and to permit the displacement of said rotor shaft therealong during assembly of the motor.

2. A brushless direct current motor as claimed in claim 1, wherein the poles of each pair of permanent magnets defining the gap there-between are of opposite polarity to produce a magnetic field in said gap and the poles of adjacent permanent magnets on each of said yokes are of different polarity, said motor being provided with six pairs of permanent magnets circumferentially spaced about said rotor so that each of said pairs of permanent magnets substantially occupies a 60 degree sector, each of said driving coils substantially occupying a 60 degree sector and mounted on said base such that parts of one driving coil are angularly spaced from corresponding parts of each of the other driving coils by 100 degrees.

including shield disc 31 rotates in the direction of said arrow 57.

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	340 "	320 "

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2. A brushless direct current motor as claimed in claim 1, wherein the poles of each pair of permanent magnets defining the gap there-between are of opposite polarity to produce a magnetic field in said gap and the poles of adjacent permanent magnets on each of said yokes are of different polarity, said motor being provided with six pairs of permanent magnets circumferentially spaced about said rotor so that each of said pairs of permanent magnets substantially occupies a 60 degree sector, each of said driving coils substantially occupying a 60 degree sector and mounted on said base such that parts of one driving coil are angularly spaced from corresponding parts of each of the other driving coils by 100 degrees.



3. A direct current brushless motor as
claimed in claim 1 or 2 wherein said
detecting means includes a shield ring formed
5 between pairs of said detecting coils, said
shield ring having cut-away portions in the
path of said detecting coils to permit the
operation of each detecting coil when said
cut-away portions are aligned therewith
10 for the activation of the driving coil associated
with said detecting coil, said detecting
coils being spaced circumferentially about
the rotor shaft at 40 degree intervals, each
of said cut-away portions defining a 40
15 degree circumferential arc about said rotor
shaft.

4. A direct current brushless motor as
claimed in claim 3, wherein said motor is
provided with three pairs of detecting coils,
said shield ring being provided with three
cut-away regions equally spaced about said
rotor shaft. 20

5. A direct current brushless motor substantially
as hereinbefore described with
reference to and as shown in the
accompanying drawings. 25

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