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(54) Title of Invention

**Reducing reactance voltage in the end turns of a
DC motor armature**

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23/38 23/40
Online databases : WPI
updated as appropriate**

Additional Fields
INT CL^s H02K 3/38 3/42 3/51

FIG.1

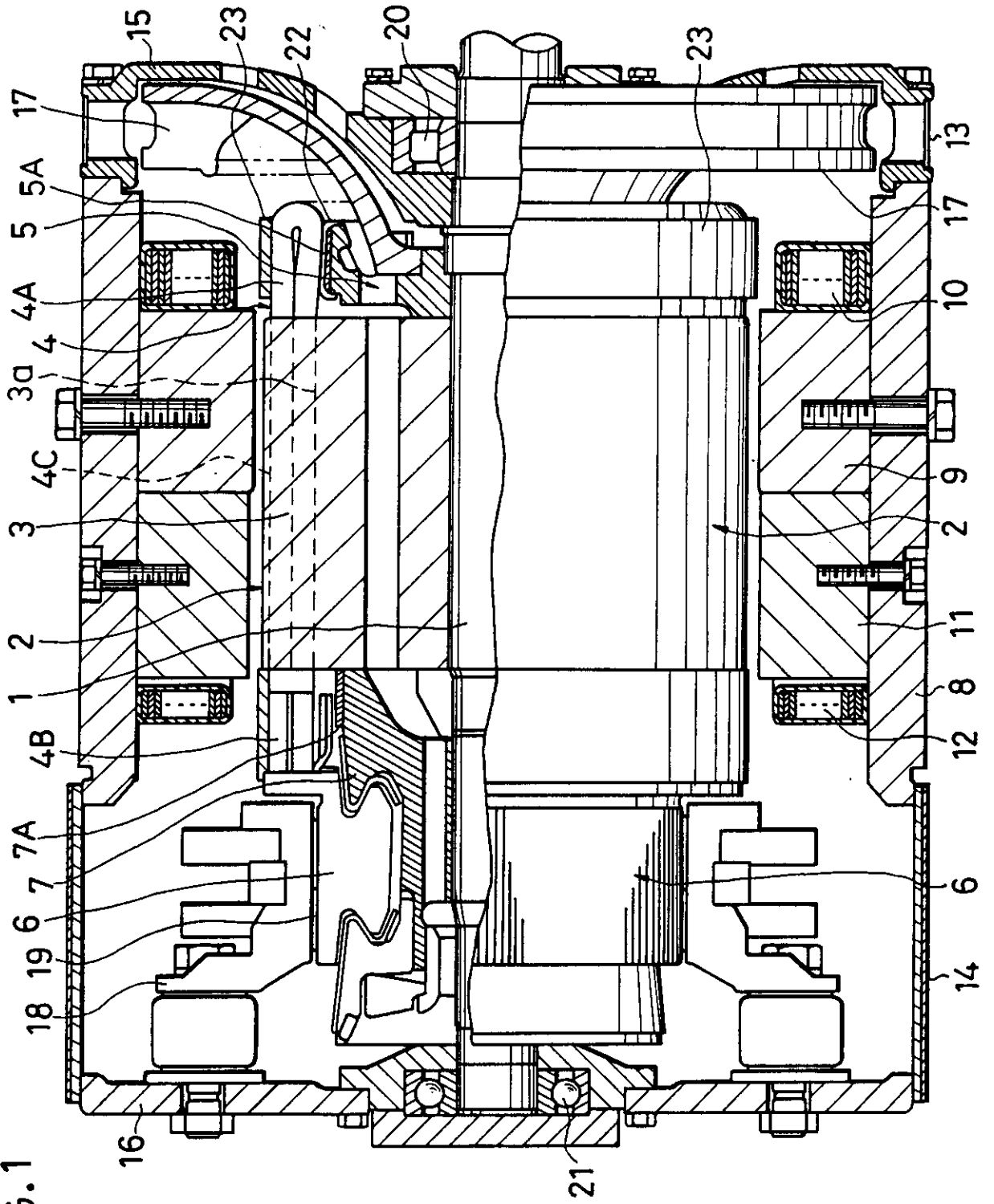


FIG. 2

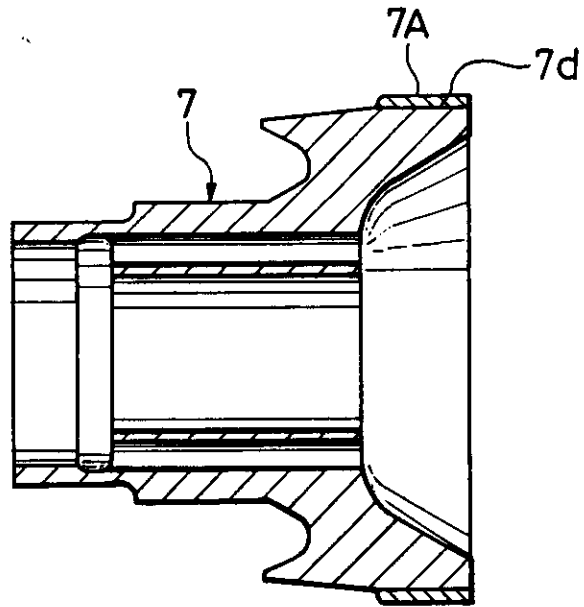


FIG. 3

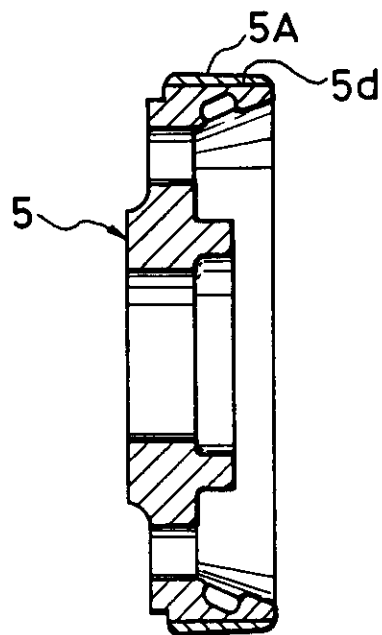
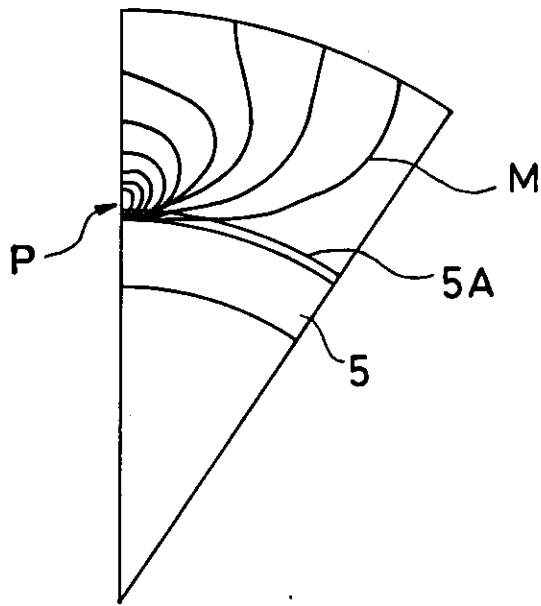


FIG. 4



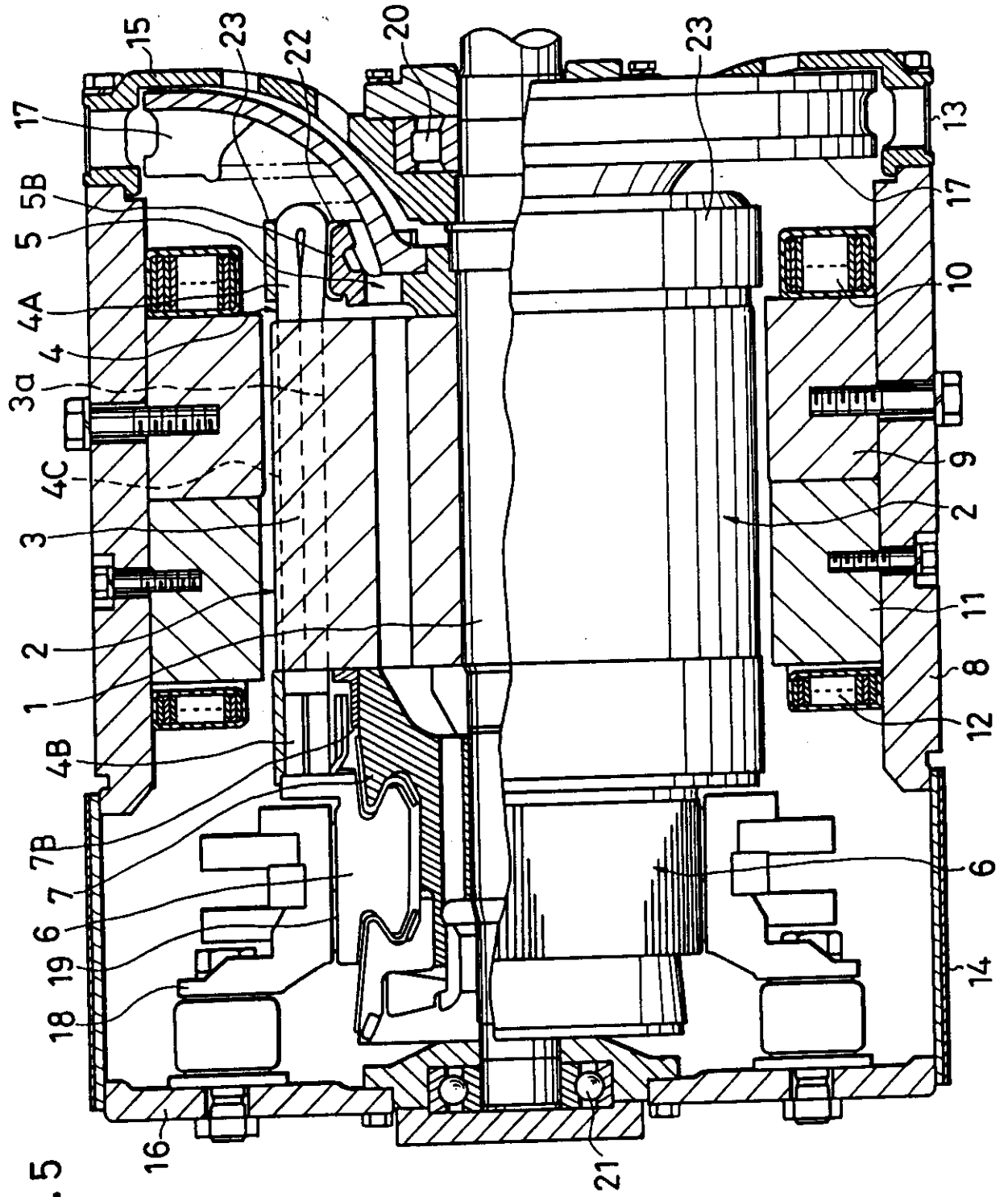


FIG. 5

FIG. 6

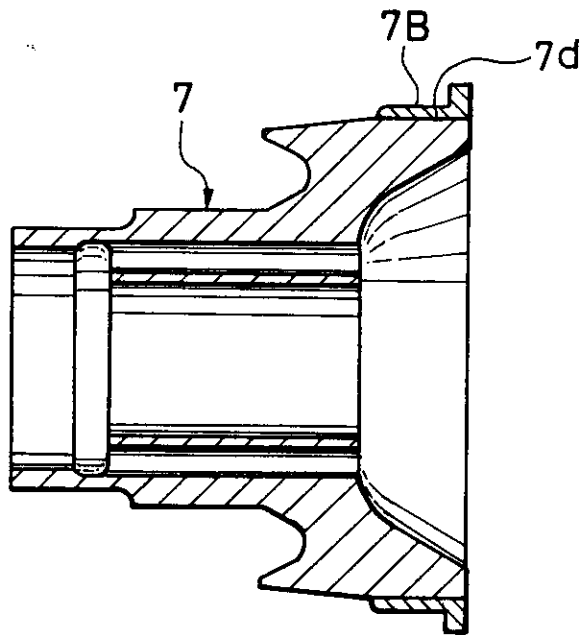


FIG. 7

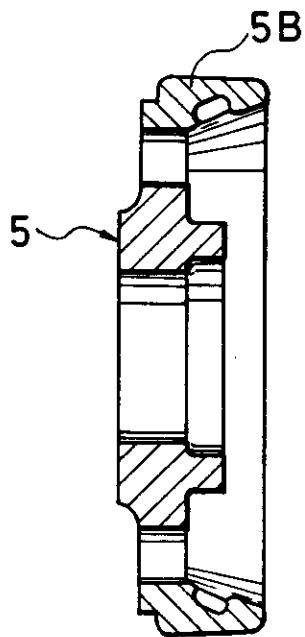
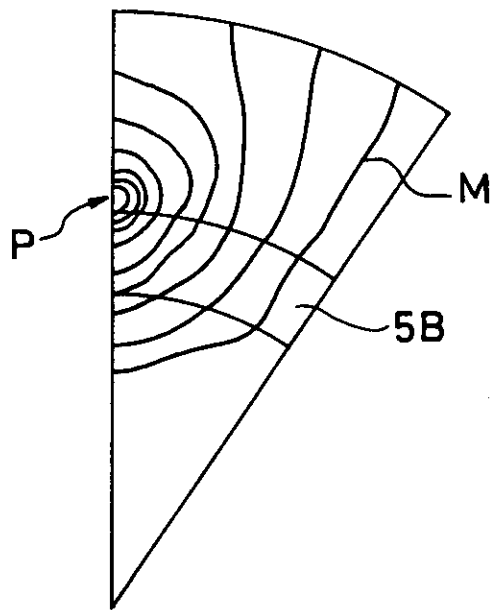


FIG. 8



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FIG. 9

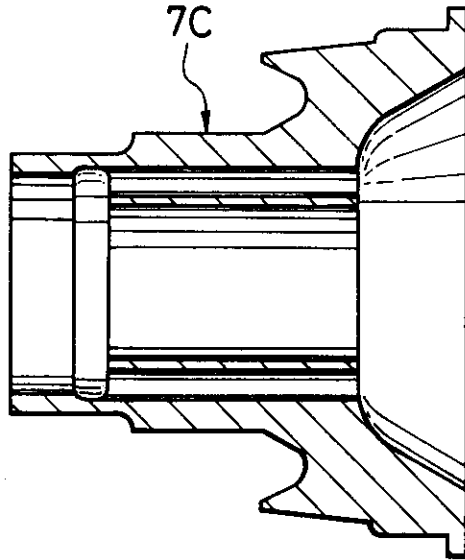
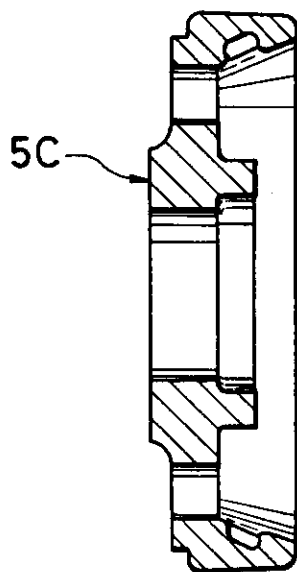


FIG. 10



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FIG.11(a)

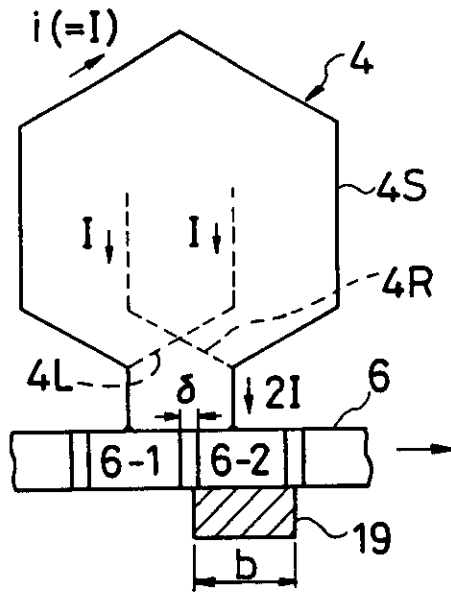


FIG.11(b)

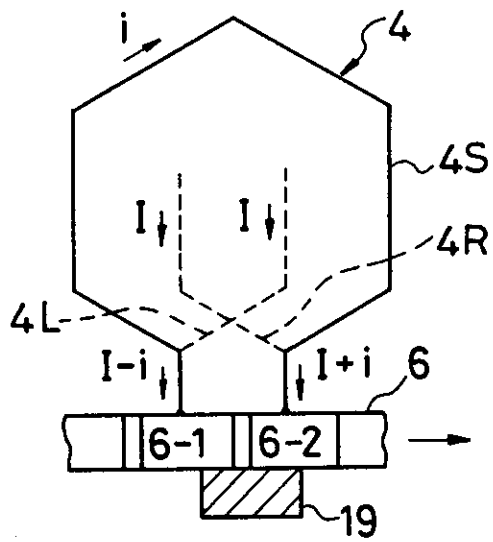
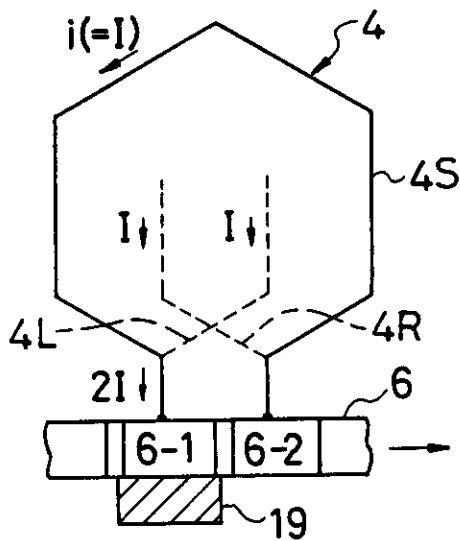


FIG.11(c)



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FIG. 12

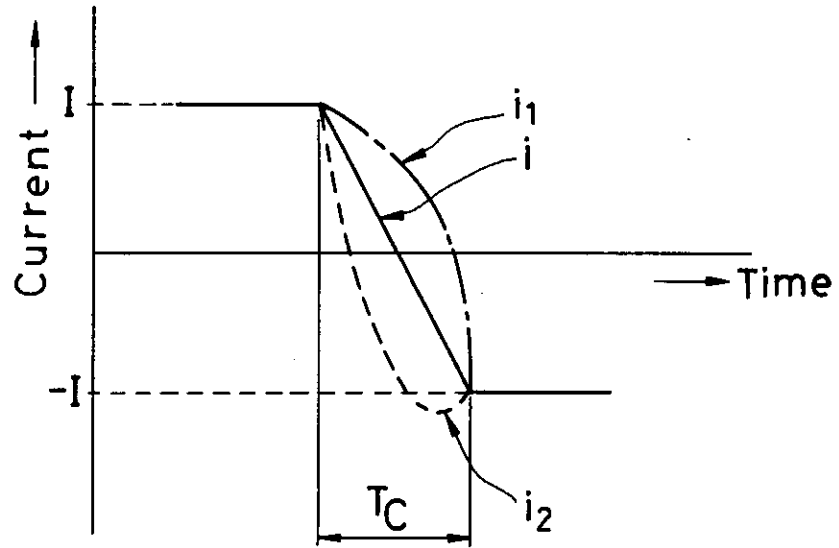
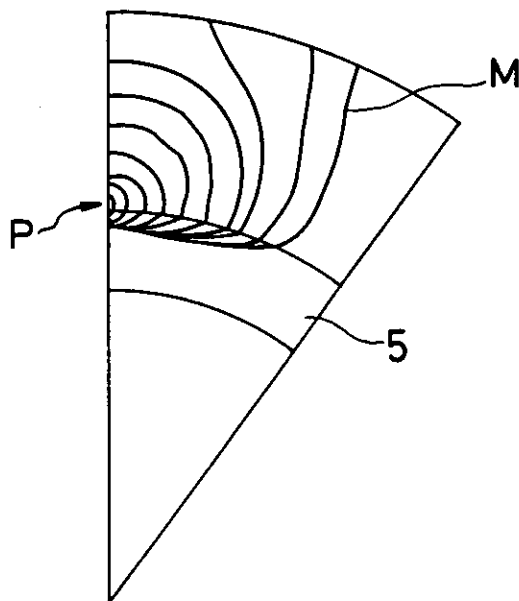


FIG. 13 (Prior Art)



REDUCING REACTANCE VOLTAGE
IN THE END TURNS OF A DC MOTOR ARMATURE

The present invention relates to the armatures of DC motors with brushes, and more particularly the present invention relates to an improvement in commutation performance of its commutator.

FIGs. 11(a), 11(b) and 11(c) are well-known illustrations showing a commutation circuit of a conventional DC motor which is constituted by a brush 19, a commutator 6 and an armature coil 4 of lap winding. FIG.11(a) shows a state before the commutation by a winding 4S of the armature coil 4. The brush 19 is in contact with only a commutator segment 6-2. In this state, a current i flowing through the winding 4S is a current I which has come from a winding 4L on the left. The current $i(=I)$ joins a current I , which has come from a winding 4R on the right, and a total current $2I$ flows into the brush 19. The commutator 6 and the armature coil 4 moves rightward against the brush 19 to a state shown by FIG.11(b). In FIG.11(b), the brush 19 is in contact with a commutator segment 6-1 and the commutator segment 6-2. In this state, the current I , which has come from the winding 4L, is separated into a current $(I-i)$ and the

current i . The current $(I-i)$ flows into the commutator segment 6-1, and the current i flows in the winding 4S. The current i joins the current I , which has come from the winding 4R, and flows into the commutator segment 6-2. When the commutator 6 and the armature coil 4 move rightward further, the brush 19 makes contact with only the commutator segment 6-1 as shown in FIG.11(c). In this state, the current i is the current I which has come from the winding 4R on the right. The current $i(=I)$ joins the current I which has come from the winding 4L on the left, and a joint current $2I$ flows into the brush 19. An absolute value of the current $i(=I)$ in this state of FIG.11(c) is the same as the current $i(=I)$ in the state of FIG.11(a), whereas a direction of the current i in FIG.11(c) is reverse to the current i in FIG.11(a). That is, the current i flowing through the winding 4S varies from $+I$ to $-I$ before and after the commutation.

FIG.12 is a graph showing variation of the current i which flows in the winding subjected to the commutation. Solid lines represent an ideal variation of the current i . In FIGs. 11(a) and 12, a commutation time period T_c has the following relation with a width b [m] of the brush 19, a thickness δ [m] between commutator segments and a circumferential speed V_c [m/sec] of the commutator 6:

$$T_c = (b - \delta) / V_c \quad \text{--- (1).}$$

When $(b-\delta)$ is 0.02 and the circumferential speed V_c is 20, the commutation time period T_c is 0.001. The commutation time period T_c is thus very short.

In FIGs. 11(a), 11(b) and 11(c), when an electromotive force is induced in the winding 4S subjected to the commutation, this electromotive force acts as a reactance voltage e_r , thereby disturbing smooth variation of the current i . Therefore, in the middle or the over middle size general DC motor, a commutating pole (not shown) is provided in a field winding (not shown) to give a compensation voltage to the winding subjected to the commutation. The reactance voltage e_r is thus compensated by the compensation voltage. Magnetic flux B generated by the commutating pole should be adjusted to satisfy the following relation:

$$e_r = L \cdot \frac{di}{dt} = k \cdot B \cdot n \quad \text{--- (2),}$$

wherein: a letter L designates an inductance of the armature coil 4; a letter n is a rotating speed of the armature; and a letter k is a constant.

In FIG.12, the armature current i varies from the DC current $+I$ to $-I$ within the commutation time period T_c . Since commutating speed $1/T_c$ is in proportion to the rotation speed n of the armature, the following relation is obtained:

$$\frac{di}{dt} \propto I \cdot n .$$

Further, since the magnetic flux B of the commutating pole is in proportion to the DC current I , the above-mentioned relation can be transformed into:

$$\frac{di}{dt} \propto B \cdot n \quad \text{--- (3).}$$

This relation (3) is also obtained by the relation (2) only when the inductance L of the armature coil is constant independent of the rotation speed n of the armature.

An ideal locus of variation of the armature current i is linear as shown by a solid line in FIG.12. However, error of adjustment or variation of inductance causes an overcommutation or an undercommutation. A locus i_1 represents variation of the armature current in the undercommutation, and a locus i_2 represents variation of the armature current in the overcommutation. For instance, when the brush 19 is about to detach from the commutator segment 6-2 (FIG.11(b)—FIG.11(c)) in a state of the undercommutation, a certain current still flows through the commutator segment 6-2. Therefore, even after detaching of the brush 19 from the commutator segment 6-2, the current flows across a minute gap between the brush 19 and the commutator segment 6-2. At that time, a spark generates between the brush 19 and the commutator segment

6-2.

In general, in case the reactance voltage e_r is excessively high at end parts of the armature coil 4, it is impossible to perfectly compensate the reactance voltage by the compensation voltage, and thereby the spark generates. For reducing the reactance voltage e_r it is effective to reduce the inductance of the armature coil. However, since the inductance of the armature coil is dependent on a configuration of gutters which are formed in an iron core of the armature, it is difficult to reduce the inductance. Instead, since the end parts of the armature coil projecting out of the iron core are held by known steel members, the inductance may increase as a result of decrease of magnetic reluctance. One of the steel members is the armature spider, and the other is the commutator spider. FIG.13 is a computer simulation showing a magnetic distribution made by the armature coil. This illustration is a part of view seen from the axial direction of the armature (not shown). It is supposed that one of windings of the armature coil is located in a position P. Numeral 5 designates the armature spider, and letter M represents magnetic fluxes made by the one of windings of the armature coil. As shown in the figure, the magnetic fluxes M join with each other in the armature spider 5. This means that a magnetic circuit is shortcircuited and shortened thereby. The magnetic

reluctance is thereby reduced, and the inductance increases accordingly. Concerning the commutator spider 7 too, a similar simulation to FIG. 13 is obtained.

Besides, when the magnetic fluxes M pass through the armature spider 5 or the commutator spider 7, the inductance is liable to vary in response to the rotation speed n of the armature as a result of generation of eddy current in steel.

An object of the present invention is to provide an armature of DC motor in which the commutator has an excellent and stable commutation performance at any rotation speed of the armature and the commutator segments are protected from being damaged.

The present invention resides in A DC motor armature comprising: an armature shaft; an armature core fixed to and around said armature shaft; an armature coil, a part of which is mounted in said armature core and both end parts of which project out of said armature core; a commutator electrically connected to said armature coil; and holding means for holding said end parts, said holding means including an electrically conductive non-magnetic member adapted to restrict inductance in one of the said end parts of the coil, the non-magnetic member being situated in a part proximate to the said one of said end parts.

The invention also resides in a DC motor armature comprising: an armature shaft; an armature core fixed to and around said armature shaft; an armature coil, a part of which is mounted in said armature core and both end parts of which project out of said armature core; a commutator electrically connected to said armature coil; an armature spider for holding one of said end parts, said armature spider including an electrically conductive non-magnetic

member adapted to restrict inductance in the said one of the said end parts of the coil, the non-magnetic member being situated in a part proximate to the said one of said end parts; and a commutator spider for holding said commutator and another of said end parts, said commutator spider including an electrically conductive non-magnetic member for restricting inductance in the said other end part of said coil, the non-magnetic member being situated in a part proximate to said another of said end parts.

In an armature embodying the present invention, the reactance voltage generated in the end parts of the armature coil is reduced, and variation of inductance caused by variation of rotation speed of the armature is reduced. Therefore, the commutation performance is stable and excellent at any rotation speed of the armature, and the commutator withstands long use.

The invention will be better understood and appreciated from the following detailed description taken in conjunction with the drawings, in which:

FIG. 1 is a cross-sectional view showing a DC motor including an armature of a first embodiment of the present invention.

FIG. 2 is an enlarged cross-sectional view showing a commutator spider 7 shown in FIG. 1.

FIG. 3 is an enlarged cross-sectional view showing an armature spider 5 shown in FIG. 1.

FIG. 4 is a computer simulation showing a magnetic distribution around the armature spider 5 shown in FIG. 1.

FIG.5 is a cross-sectional view showing a DC motor including an armature of a second embodiment of the present invention.

FIG.6 is an enlarged cross-sectional view showing a commutator spider 7 shown in FIG.5.

FIG.7 is an enlarged cross-sectional view showing an armature spider 5 shown in FIG.5.

FIG.8 is a computer simulation showing a magnetic distribution around the armature spider 5 shown in FIG.5.

FIG.9 is an enlarged cross-sectional view showing a commutator spider 7C in a third embodiment of the present invention.

FIG.10 is an enlarged cross-sectional view showing an armature spider 5C in the third embodiment of the present invention.

FIGs. 11(a), 11(b) and 11(c) are illustrations showing a commutation circuit of the conventional DC motor.

FIG.12 is a graph showing variation of a current flowing in a winding subjected to the commutation.

FIG.13 is a computer simulation showing a magnetic distribution around the conventional armature spider 5.

It will be recognized that some or all of the Figures are schematic representations for purposes of

illustration and do not necessarily depict the actual relative sizes or locations of the elements shown.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereafter, preferred embodiments of the present invention are described with reference to the accompanying drawings.

FIG.1 is a cross-sectional view showing a DC motor including an armature 2 of the present invention. In FIG.1, an armature 2 is fixed on around an armature shaft 1. An armature coil 4, which consists of plural windings connected with each other, is provided in a circumferential part of an armature core 3. In the circumferential part of the armature core 3, plural slots 3a are formed in the axial direction of the armature 2. Each intermediate part 4C of the armature coil 4 is put in the slot 3a; and each right end part 4A and each left end part 4B is projected from the slot 3a. The right end part 4A is held by an armature spider 5. The left end part 4B and a commutator 6 are held by a commutator spider 7. An inductance of a winding of the armature coil 4 consists of an inductance of the intermediate part 4C and inductances of both end parts 4A and 4B. A main pole iron core 9, a main pole coil 10, a commutating pole iron core 11 and a commutating coil 12 are fixed on an inner surface of a yoke 8 and arranged around the armature 2. A bracket 14 is connected to the

left end of the yoke 8, and a bracket 13 is connected to the right end of the yoke 8. An end plate 15 is connected to the bracket 13, and another end plate 16 is connected to the bracket 14. Thus, the yoke 8, the brackets 13, 14 and the end plates 15 and 16 form a casing of the motor. A cooling fan 17, which is provided between the end plate 15 and the armature 2, is fixed to the armature 2 so as to be rotated together with the armature 2. Brush holders 18 are fixed to the end plate 16, and brushes 19 are held by each of the brush holders 18. The brushes 19 are in contact with a commutator 6, thereby executing the commutation. Bearings 20 and 21 are provided at the right end part and the left end part of the armature shaft 1, respectively.

FIG.2 is an enlarged cross-sectional view showing the commutator spider 7 shown in FIG.1. In FIG.2, the commutator spider 7 is made of a magnetic substance such as steel. The commutator spider 7 is provided with a ring-shaped (short-cylindrical-shaped) non-magnetic member 7A on a circumferential part 7d. This non-magnetic member 7A is made of a non-magnetic substance having a conductivity higher than steel. For example, the non-magnetic member 7A is of copper.

FIG.3 is an enlarged cross-sectional view showing the armature spider 5 shown in FIG.1. In FIG.3, the armature spider 5 is made of a magnetic substance such

as steel. The armature spider 5 is provided with a ring-shaped (short-cylindrical-shaped) non-magnetic member 5A on a circumferential part 5d. This non-magnetic member 5A is made of a non-magnetic substance having a conductivity higher than steel. For example, the non-magnetic member 5A is of copper. In FIG.1, the non-magnetic member 5A is covered with an insulating material 22. The right end part 4A of the armature coil 4 is disposed on the insulating material 22, and a glass binder 23 is wound around the right end part 4A of the armature coil 4.

As shown in FIG.1, the commutator spider 7 and the armature spider 5 are disposed proximate to the left end part 4B and the right end part 4A of the armature coil 4, respectively.

FIG.4 is a computer simulation showing a magnetic distribution made by the armature coil 4 (FIG.1) disposed in a position P. This illustration is a part of view seen from the axial direction of the armature 2 (FIG.1). Numeral 5 designates the armature spider, and letter M represents magnetic fluxes made by the one of windings of the armature coil 4 (FIG.1). Numeral 5A designates the non-magnetic member of the armature spider 5. Concerning the commutator spider 7 too, a similar simulation to FIG.4 is obtained.

As shown in FIG.1, since the intermediate part 4C of the armature coil 4 is mounted in the slot . 3a of

the armature core 3, magnetic fluxes generate in a manner to encircle the armature coil 4. On the other hand, at the right end part 4A and the left end part 4B of the armature coil 4, eddy currents generate in the non-magnetic member 5A which is the conductive material disposed under the armature coil 4. Since existence of the eddy currents acts as a magnetic reluctance, the magnetic reluctance increases and an amount of the magnetic fluxes decreases accordingly. This results in decrease of a reactance voltage generated in both the end parts 4A and 4B of the armature coil 4 because of a relation that an inductance L is in proportion to an amount of the magnetic flux Φ . Besides, in a good conductive material such as copper, much eddy current generates in response to variation of current flowing in the armature coil 4, thereby reducing the amount of magnetic flux Φ and the inductance L . Therefore, even when the rotation speed varies, variation of inductance caused thereby is made small.

Inventors verified that according to this embodiment the reactance voltage decreased from 100 % (prior art) to 40 %, and verified that variation of inductance caused by variation of rotation speed decreased from 100 % (prior art) to 30 %. Further, the inventors verified the commutation performance in this embodiment, in which pure copper rings are employed for the non-

magnetic members 5A and 7A, in conformity to the commutation test specified in Japanese Industrial Standard E6101. As a result, the spark index is improved by approximately one (1.0) rank on the average in comparison with the prior art having no non-magnetic member.

FIG.5 is a cross-sectional view showing a DC motor including the armature 2 of a second embodiment. Corresponding parts and components to the first embodiment are shown by the same numerals and marks, and the description thereon made in the first embodiment similarly applies. Differences of this second embodiment from the first embodiment are non-magnetic members 5B and 7B.

FIG.6 is an enlarged cross-sectional view showing the commutator spider 7 shown in FIG.5. In FIG.6, the commutator spider 7, which is made of a magnetic substance such as steel, is provided with a non-magnetic member 7B on a circumferential part 7d. This non-magnetic member 7B is made of a non-magnetic electrically conductive substance having a conductivity lower than steel. For example, the non-magnetic member is of stainless steel.

FIG.7 is an enlarged cross-sectional view showing the armature slider 5 shown in FIG.5. In FIG.7, the armature spider 5, which is made of a magnetic substance such as steel, is provided with a non-magnetic member 5B in its circumferential part. This non-magnetic member 5B is also made of a non-magnetic electrically conductive substance such as

stainless steel having a conductivity lower than steel.

FIG.8 is a computer simulation showing the magnetic distribution at the armature spider 5B in the second embodiment. As shown in the figure, magnetic circuits are elongated, so that the magnetic reluctance increases. Therefore, the inductance and the reactance voltage decrease. Further, since stainless steel is of lower conductivity than steel, variation of inductance is made small even when the rotation speed varies.

Inventors verified that according to this second embodiment the reactance voltage decreased from 100 % (prior art) to 50 %, and verified that variation of inductance caused by variation of rotation speed decreased from 100 % (prior art) to 70 %. Further, the inventors verified the commutation performance in the second embodiment in which the stainless steel parts are employed for the non-magnetic members 5B and 7B, in conformity to the commutation test specified in Japanese Industrial Standard E6101. As a result, the spark index is improved by approximately 0.5 rank on the average in comparison with the prior art having no non-magnetic member.

FIG.9 and FIG.10 are cross-sectional views

showing a commutator spider 7C and an armature spider 5C in a third embodiment, respectively. In FIG.9, this commutator spider 7C is, as a whole, made of a conductive non-magnetic material (e.g., copper or stainless steel) which has a conductivity higher or lower than steel. In FIG.10 too, the armature spider 5C is, as a whole, made of a conductive non-magnetic material having a conductivity higher or lower than steel.

Apart from the above-mentioned embodiments, wherein a non-magnetic member is provided for both the commutator spider and the armature spider, a simplified embodiment may be such that a non-magnetic member is provided for only one of the commutator spider and the armature spider.

Although the present invention has been described in terms of the presently preferred embodiments, it is to be understood that such disclosure is not to be interpreted as limiting. Various alterations and modifications will no doubt become apparent to those skilled in the art after having read the above disclosure. Accordingly, it is intended that the appended claims be interpreted as covering all alterations and modifications as fall within the true scope of the invention.

CLAIMS

1. A DC motor armature comprising:
 - an armature shaft;
 - an armature core fixed to and around said armature shaft;
 - an armature coil, a part of which is mounted in said armature core and both end parts of which project out of said armature core;
 - a commutator electrically connected to said armature coil; and
 - holding means for holding said end parts, said holding means including an electrically conductive non-magnetic member adapted to restrict inductance in one of the said end parts of the coil, the non-magnetic member being situated in a part proximate to the said one of said end parts.

2. A DC motor armature comprising:
 - an armature shaft;
 - an armature core fixed to and around said armature shaft;
 - an armature coil, a part of which is mounted in said armature core and both end parts of which project out of said armature core;
 - a commutator electrically connected to said armature coil;
 - an armature spider for holding one of said end parts, said armature spider including an electrically conductive non-magnetic member adapted to restrict inductance in the said one of the said end parts of the coil, the non-magnetic member being situated in a part proximate to the said one of said end parts; and
 - a commutator spider for holding said commutator and another of said end parts, said commutator spider including an electrically conductive non-magnetic member for restricting inductance in the said other end part of said coil, the non-magnetic member being situated in a part proximate to said another of said end parts.

3. A DC motor armature as claimed in claim 1 or 2, in which the non-magnetic member is made of a material having higher conductivity than steel.
4. A DC motor armature in accordance with claim 1, or 2, wherein said non-magnetic member is made of a material having lower conductivity than steel.
5. A DC motor armature as claimed in claim 4 in which the non-magnetic member is of low electrical conductivity.
6. A DC motor armature as claimed in any of claims 1 to 5 in which the non-magnetic member is a ring co-axial with the armature.
7. A DC motor armature as claimed in claim 6 in which the ring is disposed radially within a projecting end part of the armature winding.
8. A DC motor armature substantially as herein described with reference to figures 1 to 4, figures 5 to 8 or figures 9 and 10 of the accompanying drawings.

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Title ARMATURE OF DC MOTOR

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