ORIGINAL

ABSTRACT

MACHINE COMPRISING A MULTIPART COIL ELEMENT

The present subject matter relates to an electromagnetic machine (100) including two parts (110, 120), which are movable relative to one another. One of the parts (110) includes a plurality of elements (130) for conducting a magnetic field (Φ), where two of the elements (130) are separated from each other by an air gap (150) intersecting a direction of the magnetic field (Φ). In one embodiment, one of the two elements (130) includes a groove (510) extending in the direction of the magnetic field (Φ) within a region of the air gap (150).

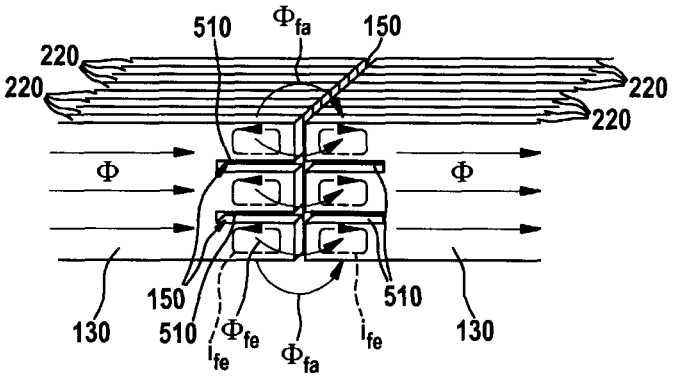


Fig. 5

I/We claim:

1. An electromagnetic machine (100) comprising two parts (110, 120) which are movable relative to one another, of which one part (110) comprises a plurality of elements (130) for conducting a magnetic field (Φ), wherein two of the elements (130) are separated from each other by an air gap (150) intersecting a direction of the magnetic field (Φ);

characterized in that,

one of the two elements (130) comprises a groove (510) extending in the direction of the magnetic field (Φ) within a region of the air gap (150).

2. The electromagnetic machine (100) as claimed in claim 1, wherein the element (130) comprises a number of stacked sheets (220) and the groove (510) is introduced in an exterior sheet (220) of the stack.

3. The electromagnetic machine (100) as claimed in claim 1 or 2, wherein each of the two elements (130) have a groove (510), wherein the grooves (510) are aligned.

4. The electromagnetic machine (100) as claimed in one of the preceding claims, wherein each of the two elements (130) have a groove (510) which are arranged along the air gap (150) offset from one another.

5. The electromagnetic machine (100) as claimed in claim 4, wherein the sheets (220) of the two elements (130) opposing one another with respect to the air gap (150) have different numbers of the grooves (510).

6. The electromagnetic machine (100) as claimed in any one of the claims 2 to 5, wherein the each different sheet (220) of the elements (130) have a groove (510), wherein the grooves (510) of the element (130) are offset from one another.

7. The electromagnetic machine (100) as claimed in one of the preceding claims, wherein at least one of the elements (130) is circumscribed by a coil (140) for generating the magnetic field (Φ).

8. The electromagnetic machine (100) as claimed in one of the preceding claims, wherein the electromagnetic machine (100) is an electric motor or generator, and wherein the magnetic field (Φ) in the air gap (150) extends in a radial direction of the electric motor or generator.

9. The electromagnetic machine (100) as claimed in any one of the claims 1 to 7, wherein the electromagnetic machine (100) is an electric motor or generator, and wherein the magnetic field (Φ) in the air gap (150) extends in a circumferential direction of the electric motor or generator.

10. The electromagnetic machine (100) as claimed in any one of the claims 1 to 7, wherein the electromagnetic machine (100) is a linear motor.

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To
The Controller of Patents
The Patent office at New Delhi

TECHNICAL FIELD

The present subject matter relates generally to the field of electromagnetism and in particular to an electromagnetic machine according to the preamble of the independent claim 1.

BACKGROUND

Machines, which convert electrical energy into mechanical energy or vice versa, usually include two relatively movable parts between which a magnetic field acts. At least one of the parts includes coil windings for converting the electrical current in a magnetic field or vice versa. Particularly, magnetic flux elements are used in the area of such coil windings in order to conduct and to pool the magnetic field.

For technical reasons, the magnetic flux elements are often designed in several parts, where an air gap exists in the region between adjacent flux elements, which can affect the conduction of the magnetic field.

SUMMARY

This summary is provided to introduce concepts related to electromagnetic machines and the concepts are further described below in the detailed description. This summary is neither intended to identify essential features of the claimed subject matter nor is it intended for use in determining or limiting the scope of the claimed subject matter.

In one embodiment, an electromagnetic machine is disclosed. The electromagnetic machine includes two parts, which are movable relative to one another. One of the parts includes a plurality of elements for conducting a magnetic field, where two of the elements are separated from each other by an air gap intersecting a direction of the magnetic field. In one embodiment, one of the two elements includes a groove extending in the direction of the magnetic field within a region of the air gap.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages, features and details will emerge from the description below, in which with reference to the figures, various embodiments of the present subject matter are shown. Thereby, the characteristics mentioned in the claims and in the description can be essential for the present subject matter individually or in any combination, wherein:

Figure 1 shows a brushless electric motor having a stator in a first embodiment.

Figure 2 shows a brushless electric motor having a stator in a second embodiment.

Figure 3 shows a region of magnetic flux elements of the stator arranged in I-shape from the figure 1.

Figure 4 shows a region of magnetic flux elements of the stator arranged in T-shape from the figure 2.

Figure 5 shows the region of figure 3 with flux elements that are provided with grooves.

Figure 6 shows the region of figure 4 with flux elements which are provided with grooves.

Figure 7 A-E shows variations of the adjacent flux sheets of the magnetic flux elements from figures 5 and 6.

DETAILED DESCRIPTION

The object of the present subject matter is to provide an electromagnetic machine, in which an improved transfer of magnetic fields between adjacent elements of a magnetic flux element is provided.

The present subject matter solves this problem by an electromagnetic machine having the features of claim 1. Dependent claims describe the advantageous embodiments of the present subject matter.

An electromagnetic machine includes two relatively movable parts, which include a plurality of elements for conducting a magnetic field. Two of the elements are separated from each other by a magnetic field intersecting the direction of the air gap. One of the elements within the region of the air gap has a groove running in the direction of the magnetic field. The elements can be a part of a stator of an electric motor and the stator carries the coil windings.

The surface of the elements is bound by the groove, in which eddy currents are induced based on the magnetic fringe fields within the region of the air gap, so that the eddy currents are limited. Thus, minimizes the heating of the elements and maximizes the efficiency of the electromagnetic machine.

The element may include a number of stacked sheets, and the groove may be incorporated into an exterior sheet of the stack. Eddy currents which result in eddy current losses occur primarily in the region on the outermost sheets, so that an efficient reduction of the eddy current losses can be realized and at the same the loss of material by grooves is avoided in the region between an uppermost and lowermost sheet.

Each of the two elements can have a groove, where the grooves are aligned to each other. In another embodiment, the grooves of the two elements along the air gap may be offset to each other. Accordingly, the sheets of the two elements opposing one another with respect to the air gap can have different numbers of the grooves.

In one embodiment, each different sheet of the elements have a groove, where the grooves of the element are offset from one another.

By means of these possible variations, an adjustment of the grooves takes place, for example, in geometrical conditions, particularly the width of the element. In addition, another efficient suppression of surrounding areas may be achieved by balancing of the grooves of both elements and thus by eddy currents.

At least one of the elements may be circumscribed by a coil for generating the magnetic field. The electromagnetic machine may include a stator or a rotor, which has multiple elements for conducting a magnetic field, where the coils can be wound on each single element or already-wound coils can be pushed onto the elements before the elements are joined to the stator or the rotor. Intermediate spaces between the assembled elements, which are provided for receiving the coils, can be used in particularly efficient manner. The packing density of coil windings of the coil may be maximized in the gaps; thereby performance and efficiency of the electromagnetic machine can be improved.

The machine may be particularly an electric motor or generator, wherein the magnetic field in the air gap extends in a circumferential direction of the electric motor and/or generator. Thus, the present subject matter can be used in a known magnetic flux element with several I-shaped elements.

Alternatively the magnetic field extends in the air gap in a radial direction of the electric motor or generator. Thus, the present subject matter can also be set at another known magnetic flux element with several T-shaped segments, which are enclosed by a ring insert.

In a further embodiment, the present subject matter can be used on a linear motor having a multipart magnetic flux element.

Figure 1 shows a brushless electric motor 100 (this can be referred to as an electromagnetic machine 100 or an electric motor 100) with a stator 110 in a first embodiment and a rotor 120. The stator 110 includes a plurality of substantially T-shaped magnetic flux elements 130 (this term can be referred to as an element 130 or a magnetic flux element 130), which are arranged circumferentially, where they surround the rotor 120. Each of the magnetic flux elements 130 carries a coil 140. In the illustrated

exemplary embodiment, three different types of coils 140 are used, which are shown as a solid line, dashed line and dotted line. Coils of this type are electrically connected together resulting in a three-phase motor in the present example.

The rotor 120 includes at least one permanent magnet (not shown). Alternating electrical currents are applied to the coils 140 in order to enable the rotor 120 in rotation relative to the stator 110. Variable magnetic fields are generated in the coils 140 by the alternating electric currents, which are passed by means of the magnetic flux elements 130 and coupled together. The magnetic north and south poles of the magnetic field induced by the electric alternating fields produces magnetic flux elements 130 at the inwardly facing regions of the T-shape. The generated magnetic north and south poles works on magnetic south and/or north poles of the permanent magnets of the rotor 120 in attractive or repulsive manner, so that the rotor 120 aligns itself in the generated magnetic field.

By the alternating electrical control, the coils 140 migrate the magnetic field generated by the stator 110 around a rotational axis 105 of the electric motor 100, and the rotor 120 due to the magnetic coupling of this rotational movement. The rotational speed of the rotor 120 can be achieved by the appropriate control of the coils 140.

In an analogous manner, the electric motor 100 may be used to induce the flow of current in the coils 140 by the rotational movement of the rotor 120 relative to the stator 110. In this case, the electric motor 100 operates as a generator. The designations of the rotor 120 and stator 110 are interchangeable according to a perspective of a viewer and are not restrictive for the embodiment shown. In another embodiment, the magnetic flux elements 130 and the coils 140 may be affixed to the rotor 120 of the electric motor 100.

The individual electromagnetic flux elements 130 are provided with coils 140, while each of the elements 130 is wound individually with the coil 140, or while a previously wound coil 140 is pushed onto the region of the individual magnetic flux element 130 facing the rotational axis 105. Only after the magnetic flux elements 130 are provided with coil 140, the magnetic flux elements 130 are assembled to the stator 110. Air gaps 150 remain between adjacent magnetic flux elements 130, which may affect the transfer of the magnetic field between the adjacent magnetic flux elements 130. The air gaps 150 between the magnetic flux elements 130 are running radially to the rotational axis 105 of the electric motor 100.

Figure 2 shows a brushless electric motor 100 with a stator 110 in the second embodiment and the rotor 120 of figure 1. The magnetic flux elements 130 are connected

to each other along the inner periphery of the stator 110. The magnetic flux elements 130 are enclosed by a ring element 210, for example by pressing in the flux elements 130 in the ring element 210. The air gaps 150 between the magnetic flux elements 130 and the ring element 210 run in a circumferential direction about the rotational axis 105 of the electric motor 100. Otherwise, the above has been stated in figure 1.

Figure 3 shows a region of magnetic flux elements 130 of the stator 110 arranged in I-shape from the figure 1. The left and the right magnetic flux element 130 are bound respectively at the air gap 150, which is shown enlarged for more accessible understanding. Each of the magnetic flux elements 130 is formed by a stack of flux sheets 220 (the flux sheets 220 can also be referred to simply as sheets 220).

Furthermore, a variable magnetic flux Φ is transmitted between the magnetic flux elements 130. Variable magnetic fluxes Φ_{fe} and Φ_{fa} are present in an edge region of the magnetic flux elements 130 on both sides of the air gaps 150. The magnetic flux Φ_{fa} extends substantially in a plane of extension of flux sheets 220. An inlet and outlet angle of the variable magnetic edge flux Φ_{fa} relative to the flux sheet 220 amounts to 90 degrees. The induced eddy current i_{fa} by the variable magnetic edge flux Φ_{fa} is very small, because the geometrical region, in which the eddy current i_{fa} can be built, is limited by the thickness of one of the flux sheets 220. The flux sheet 220 of an electric motor 100 is 0.5 mm thick. The eddy currents i_{fa} are therefore small enough to be neglected in the present context.

The inlet and outlet angle of the variable magnetic edge flux Φ_{fe} relative the flux sheet 220 is 90 degrees. The eddy current i_{fe} which is induced by the variable magnetic edge flux Φ_{fe}, can achieve a significant size due to the size of the region of flux sheets 220, in which they can deploy. This region is limited by the width of the flux sheets 220, which can be as large as up to 20 times the thickness of the flux sheets 220 in the small electric motor 100. Accordingly, the eddy current i_{fe} induced by the variable magnetic edge flux Φ_{fe} can be large enough to cause heating of the flux sheets 220 in the region of the air gap 150 and impair the efficiency of the electric motor 100.

Figure 4 shows a region of magnetic flux elements 130 of the stator 110 arranged in T-shape from the figure 2. From the lower magnetic flux element 130, a variable magnetic flux Φ on the air gap 150 is transferred across an upper magnetic flux element 130 to divide flux in equal parts to the right and left. Both magnetic flux elements 130 are guided in figure 3 as a stack of flux sheets 220. In Figure 4, variable magnetic edge fluxes Φ_{fe} and Φ_{fa} are formed in the air gap 150.

The inlet and outlet angle of the variable magnetic flux Φ_{fa} relative to the flux sheet 220 amounts to 90 degrees. As explained above with reference to figure 3, only small eddy currents i_{fa} are induced by the variable magnetic edge flux Φ_{fa}, since these are made available due to the limited thickness of the flux sheets 220 with only little space for development.

The inlet and outlet angle of the variable magnetic edge flux $\Phi_{fe,}$ relative to the flux sheet 220, amounts to 90 degree. The eddy currents i_{fe} induced by the variable magnetic edge flux Φ_{fe} have a space limited only by the flux sheets 220 for development, and can reach significant values. The eddy currents i_{fe} can lead to heating of the magnetic flux elements 130 in the region of the air gap 150 and reduce efficiency of the electric motor 100.

Figure 5 shows the region of figure 3 with magnetic flux elements 130, which are provided with grooves 510. The grooves 510 extend in the direction of the magnetic field Φ, and the grooves 510 are aligned in the two magnetic flux elements 130 in a paired manner.

By the grooves 510, the flux sheet 220 is divided into several regions within the region of the air gap 150 in the vertical direction. Eddy currents i_{fe}, which are caused by the variable magnetic edge flux Φ_{fe}, therefore have a significantly smaller space to unfold, so that the sum of all eddy currents i_{fe} is significantly reduced. As a result, decreases the tendency of the magnetic flux elements 130, to heat up within the region of the air gap 150 and thus the efficiency of the electric motor 100 is increased.

The grooves 510 are merely introduced into the foremost illustrated flux sheet 220.

The flux sheets 220, which do not lie outside, but between two flux sheets 220, carries no grooves 510, because the variable magnetic flux Φ_{fe} does not exist in these flux sheets 220. Not shown in figure 5 are the grooves 510 within the rear flux sheet 220, which act according to the illustrated grooves 510 in the front flux sheet 220.

Figure 6 shows a region of figure 4 with the magnetic flux elements 130, which are provided with grooves 510. In a corresponding manner as described above with reference to Figure 5, the embodiment shown in Figure 6 differs from the embodiment shown in Figure 4, thereby the grooves 510 are introduced into the upper and lower magnetic flux element 130.

Two of the grooves 510 within the upper magnetic flux element 130 are aligned in pairs with the grooves 510 in the lower magnetic flux element 130. Two further grooves

510 within the upper magnetic flux element 130 are located opposite to an outer edge region of the lower magnetic flux element 130. Also shown in the figure 6, the grooves 510 cause a limitation of space in the magnetic flux elements 130, in which the eddy currents i_{fe} induced by variable magnetic edge flux Φ_{fe}, can unfold itself. In the sequence, the sum of the eddy currents i_{fe} is smaller than the sum of the eddy currents i_{fe} in the figure 4.

The grooves 510 extend as shown in figure 5, only within the top and not visible in the bottom flux sheet 220 of the upper and lower magnetic flux element 130.

Figure 7 shows variations of the adjacent flux sheets 220 of the magnetic flux elements 130 from figures 5 and 6. As shown in Figures 7A to 7D, any numbers of grooves 510 can be inserted in the magnetic flux elements 130 and/or their outer flux sheets 220. The grooves 510 in the flux elements 130 adjacent to the air gap 150 and/or outer lying flux sheets 220 are aligned in pairs as shown in the Figures 7A and 7B, or may be offset from one another, as shown in the figures 7C and 7D. The numbers of the grooves 510 may be equal in the both magnetic flux elements 130 and/or flux sheets 220, as shown in Figures 7A and 7B, or not, as shown in the figures 7C and 7D.

Figure 7E shows a variant of the present subject matter, where the grooves 510 illustrated with solid lines are introduced in the top of two stacked flux sheets 220. The grooves 510 face opposite to each other with respect to the air gap 150, as shown in FIG 7A. The grooves 510 shown with dashed lines are introduced in the lower flux sheet 220 lying under the upper flux sheet 220, where the grooves 510 are disposed as shown in Figure 7B. In further embodiments, the grooves 510 can be introduced in other relative positions, for example, as shown in Figures 7 C and 7 D.

Although the subject matter has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternate embodiments of the subject matter, will become apparent to persons skilled in the art upon reference to the description of the subject matter. It is therefore contemplated that such modifications can be made without departing from the spirit or scope of the present subject matter as defined.