

Description

Electric Machine

5 The invention relates to an electric machine having a one-piece can which is arranged between a stator and a rotor, and whose tubular casing, which is loaded with external pressure by means of a cooling fluid within a machine housing, is composed of composite fiber
10 material. Electric machine is understood here to mean, in particular, an electric motor or generator, preferably with an integrated converter, as an output of an assembly or auxiliary assembly of a utility vehicle which operates as a motor and/or generator.

15 The electric machine is typically operated by means of power electronics (converter, in particular frequency converter, DC/AC or AC/DC converter or the like). The electronics suitably have a bridge circuit composed of
20 semiconductor switches whose number depends, like the number of bridge branches, on the phase number of the electric machine, wherein three-phase or multi-phase motors and generators are customary.

25 Depending on the operation of the electric machine as a motor or as a generator, the electric power is fed either to the machines for the desired rotational speed and the intended torque, or the electric power is extracted from the electric machine and extracted for
30 assemblies downstream, for example a utility vehicle. In the operating mode as a generator, the multi-phase alternating current which is produced in the generator mode is converted by means of the electronics (converter) into a direct current which is then fed,
35 for example, to the respective assembly or load via an intermediate circuit.

The stator of the electric machine is cooled by means of a cooling fluid in order to dissipate the heat

occurring owing to the power loss caused by operation. The cooling fluid is selected as a function of the field of use and of the power of the electric machine, wherein usually oil is used. The cooling fluid is
5 preferably conveyed by means of a pump which is actuated by the electric machine itself or by means of a separate drive.

In order to avoid the rotor of the electric machine
10 being braked by the cooling fluid owing to the increased friction and therefore the efficiency level of the electric machine being reduced, the latter have what is referred to as a can. This can is located at least partially in the gap between the stator and the
15 rotor and separates them from one another. Conventional cans are composed, for example, of metal or glass-fiber-reinforced plastic.

DE 10 2009 052 932 A1 discloses an electric machine
20 having a stator inside a stator housing. The stator comprises a coil package which has an axially extending effective area. The coil package is configured therein in order to interact electro-dynamically with the rotor. The winding heads of the coil package are
25 arranged outside the effective area here. The stator housing is separated hermetically from the rotor of the electric machine by means of a can. The can extends axially only at the effective area of the coil package, and is therefore comparatively short.

30 The invention is based on the object of specifying an improved electric machine.

This object is achieved according to the invention by
35 the features of claim 1. Advantageous refinements, developments and variants are the subject matter of the dependent claims.

The electric machine is, for example, an electric generator or, particularly preferably, an electric motor. The electric machine has a stator composed, in particular, of a ferromagnetic material. For example, 5 the stator comprises a number of laminations joined together to form a laminated core, said laminations being arranged essentially perpendicularly with respect to an axial direction of the electric machine. In particular, the laminations are rectangular or 10 circular. In addition, the stator has a coil package with electric conductors which run in the axial direction and which are wrapped around the laminations and/or guided through the laminations in grooves (ducts) provided for that purpose. Arranged outside the 15 laminated core are winding heads which connect the axially extending conductors to one another electrically.

The stator has a cutout running centrally and in the 20 axial direction, a rotor being arranged inside said cutout in a rotor space. The rotor is freely movable here in a rotational direction. In other words, it is possible to rotate the rotor about a rotational axis which extends in the axial direction without said rotor 25 touching the stator. The rotor is constructed, for example, from a laminated core on which or in which, in particular, a number of permanent magnets or electromagnets are mounted. It would also be conceivable for the rotor not to have a magnet, in the 30 manner of an induction motor.

The rotor is made to rotate by energizing the laminated core of the stator, or rotation of the rotor brings about a flow of electric current inside the laminated 35 core. In this context, the electromagnetic field which forms between the rotor and the stator, in particular in the region of the laminated core of the rotor and/or the stator, is essentially constant and, in particular,

at a maximum, but at least comparatively large. The region of the comparatively large electromagnetic field is referred to as the effective area. In particular, the term effective area refers to that region between
5 the rotor and the stator whose axial projection is covered by a projection onto the axial direction of at least one of the laminated cores of the stator or of the rotor.

10 The flow of the electric current through the coil package heats up the stator. In order to avoid damage to the stator, the latter is therefore cooled by means of a cooling fluid. The cooling fluid is, for example, an oil which has, in particular, the property of an
15 electrical insulator.

For example, the comparatively cold cooling fluid is conducted into a stator space which accommodates the stator. The cooling fluid washes around the laminations
20 of the stator and/or within the laminations there are cooling ducts through which the cooling fluid is directed. In this way, the cooling fluid is heated and the stator is cooled. The heated cooling fluid is pumped out of the stator space or conveyed out of it
25 and cooled outside the machine housing, in particular by means of a heat exchanger. In order to ensure that the cooling fluid flows through the stator space, the cooling fluid is expediently under pressure.

30 In order to avoid the cooling fluid penetrating the rotor space, a can is located between the rotor and the stator. This makes it possible to keep the rotor space free of the cooling fluid, with the result that when the latter rotates comparatively low losses occur. In
35 particular, what are referred to as churning losses of the rotor are avoided by means of the can.

The can is in one piece and a hollow cylinder with a tubular casing which is manufactured from a composite fiber material. In other words, the tubular casing is composed of one fiber or a number of fibers which
5 is/are embedded in a so-called matrix. The thickness of the tubular casing, that is to say the radial extent of the tubular casing between the internal diameter and the external diameter thereof is between 2.5 mm and 0.5 mm. In this way, the can is stable with respect to
10 external pressure and buckling failure of the can can be prevented. Nevertheless, the can is comparatively thin, with the result that the electric machine has a comparatively high efficiency level.

15 The can is suitably surrounded directly by the stator and, in particular, by the laminated core thereof. At any rate, a gap between the can and the stator is comparatively small. The stator therefore preferably has a stabilizing effect on the can, the casing
20 thickness of which can therefore be reduced. In the case of comparatively large loading with external pressure the can would buckle inwards. Regions of the can would be pressed outward in the course of the inward buckling. For example, in the case of a freely
25 located can and loading with external pressure in a pressure direction which runs through the central axis of the can, these regions are located in an extension direction which also runs through the central axis of the can but perpendicularly with respect to the
30 pressure direction. In other words, the circuit cross section of the can would be deformed elliptically owing to this loading with external pressure. Since the stator which is applied to the can prevents this deformation toward the outside, the buckling of the can
35 toward the inside is reliably prevented.

In one preferred embodiment of the invention, the casing thickness of the can is less than 2 mm and

greater than 1 mm and, in particular, the casing thickness is greater than 1.2 mm and, in particular, less than 1.7 mm. The casing thickness is particularly preferably between 1.3 mm and 1.5 mm and, in particular, 1.4 mm.

The can expediently extends over the effective area between the stator and the rotor. In particular, at least the can is longer than the laminated core of the stator and arranged inside the stator in such a way that the entire laminated core is shielded from the rotational axis. This makes it possible to keep the effective area essentially free of ferromagnetic materials which have an adverse effect on the efficiency level of the electric machine. If, specifically, such a material were located there, parasitic electric currents could arise therein, which could weaken the electromagnetic field.

Although the susceptibility of the can buckling owing to a high external pressure increases as a function of the increasing length of the can, that is to say the critical buckling pressure decreases, this increase becomes smaller as a function of the increasing length of the can. In contrast, the casing thickness of the can is dependent in an essentially quadratic fashion on the external pressure. Although the critical buckling pressure is therefore slightly reduced, during the manufacture of the electric machine there are no fabrication problems owing to any connection of the can to further elements within the stator.

In particular, the fiber of the composite fiber material is wound at a winding angle with respect to the longitudinal direction of the can tube during the manufacture of the can. A winding angle of 90° denotes an angle which is perpendicular with respect to the longitudinal direction of the can tube. A can having a

winding angle of 90° would accordingly be constructed essentially from a number of rings arranged in a row.

5 In one expedient embodiment of the invention, the angle is, however, less than 90° and greater than 70° . The winding angle is suitably greater than 75° here. In this way, a comparatively high degree of stability of the can is realized in the radial direction without having to tolerate the possibility of the can falling apart
10 into individual disks.

The fiber is preferably composed of glass and the composite fiber material is a glass-fiber-reinforced plastic (GFP). The plastic is, in particular, epoxy
15 resin. It would also be conceivable for the composite fiber material to be a carbon-fiber-reinforced plastic (CFP).

In one particularly suitable embodiment of the
20 invention, the winding angle is greater than 80° and is at least 82° . In particular, the winding angle is 88° since it has been shown that a winding angle of 88° brings about a particularly high level of stability of the can in the radial direction and at the same time
25 has a level of axial stability which is suitable for the use within the electric machine.

A coating layer is expediently applied to the tubular casing of the can. The coating layer surrounds the can
30 on the outside and is therefore located between the stator and the can, wherein the latter bears against the can. The coating layer prevents the cooling fluid penetrating the can, which in this way could be softened or damaged in some other way. The coating
35 layer is preferably composed of a polymer.

The at least front face, but suitably both front faces of the can, is/are advantageously not in contact with

any other element of the electric machine. However, at least the can is not loaded on the front face, which leads to comparatively low mechanical loading of the can in the axial direction. This makes it possible to
5 optimize the can, particularly with respect to the radial stability thereof.

The can is preferably fitted axially onto a sleeve. The sleeve bears on the inside against the can and serves
10 as a positioning element for the can. Owing to the fact that the sleeve bears on the inside of the can, the front faces thereof can be free, that is to say without any contact. Likewise, the sleeve acts as a means of stiffening the can in the radial direction. The sleeve
15 is composed, in particular, of a steel (stainless steel) and does not project into the effective area between the stator and the rotor.

The sleeve is fitted onto a collar of an end plate of
20 the machine housing. The collar of the end plate runs accordingly in the radial direction within the sleeve. The collar is connected, for example, in one piece to the end plate. The can is expediently fitted on both sides onto a sleeve, which is in turn fitted in each
25 case onto a collar.

The use of the sleeve which is fitted onto the collar of the end plate onto which the can is fitted can be independent of the casing thickness or of the rest of
30 the configuration of the can and is instead considered to be an independent invention.

In one advantageous form of the invention, the sleeve is divided in the axial direction into a first axial
35 section and a second axial section or has at least the latter. The first axial section is located at least partially in the can and therefore is in direct or indirect contact with the can, for example via a

gasket. In this case, the radial distance between the outermost surface of the first section and the rotational axis is essentially the same or only comparatively slightly smaller than the radial distance
5 of the innermost surface of the can.

The second axial section adjoins the first axial section and the outermost surface of said second axial section has a radial distance from the rotational axis
10 which corresponds essentially to the radial distance between the outer casing face of the can and the rotational axis. In other words, the second axial section is aligned with the can.

15 During the manufacture of the can, the fiber is, for example, applied directly to the sleeve and therefore produces a fixed connection between the sleeve and the can. However, in one suitable embodiment the can is manufactured separately from the sleeve. So that the
20 cooling fluid does not pass through between the sleeve and the can when there is a raised pressure, a gasket is located between the sleeve and the can. The gasket is, in particular, an O-ring.

25 The sleeve is expediently sealed with respect to the collar of the end plate by means of a further gasket. The electric machine therefore requires comparatively few sealing points, which sealing points could constitute a residual risk of leaks.

30 The axial thermal expansion of the machine housing is expediently essentially the same as that of the can. For example, the winding angle and/or the material of the fiber of the can and/or the plastic thereof are
35 suitably selected for this. It would also be conceivable to adapt the machine housing to the can. In this way, when the electric machine heats up during operation the can and the machine housing expand

essentially uniformly so that no leaks, through which, for example, the cooling fluid could enter the rotor space, occur between the can and the housing. Likewise, mechanical loading of the can and of the machine housing in the axial direction is avoided if the connection between them is comparatively strong.

The electrical machine expediently has a power level which is less than 1 MW and advantageously between 50 kW and 0.5 MW. In particular, the electric motor has a power level below 500 kW during normal operation, wherein, in particular, during any overload operation the power level is briefly higher than this limit. With these power limits it is usually necessary to cool the stator with the cooling fluid. In this context, the cooling fluid is suitably below a pressure of up to 3 bar in order to ensure the cooling fluid flows through the stator. With this pressure the can does not buckle out in the direction of the rotor and the reliable operation of the electric machine is ensured.

An exemplary embodiment of the invention will be explained in more detail below with reference to a drawing, in which:

Figure 1 shows a sectional illustration of an electric machine having a can, and

Figure 2 is a perspective view of the can.

Corresponding parts are provided with the same reference symbols in all the figures.

Figure 1 illustrates an electric machine 2 with an axial direction 4 and a radial direction 6 in a sectional illustration. The section extends along a rotational axis 8, which is parallel to the axial direction 4. The electric machine 2 is, in particular,

an electric motor which is used inside a utility vehicle, for example inside what is referred to as a snow groomer, for driving the same or for driving any secondary assemblies. The power level of the electric
5 motor is, for example, 140 kW.

The electric machine 2 has a machine housing 10 made of aluminum, of which an A-side end plate 12 and a B-side end plate 14 are illustrated here. Bearings 16, for
10 example ball bearings, are mounted on the end plates 12, 14. The bearings 16 are each located here inside a collar 18. Each collar 18 is hollow-cylindrical and projects into the interior of the machine housing 10. Within the bearing 16 there is a cylindrical shaft (not
15 illustrated). The shaft is arranged concentrically with respect to the rotational axis 8 and the bearings 16. During operation of the electric machine 2, the shaft rotates about itself and the rotational axis 8. For example the secondary assemblies of the utility vehicle
20 are operatively connected to the shaft.

A schematically shown rotor 20 is concentrically mounted on the shaft. The rotor 20 has, for example, a laminated core composed of individual laminations
25 within which or on which permanent magnets are mounted. In other words, the electric machine 2 is a permanently excited electric motor. The rotor 20 is located inside a rotor space 22 which is filled with air. The rotor space 22 is divided off from a stator space 24 by means
30 of a can 26. The longitudinal direction 28 of the can 26 is parallel to the rotational axis 8 and the axial direction 4.

The can 26 is not loaded at its front faces 30, and
35 therefore no, or comparatively small, axial forces act on the front faces 30 owing to the mounting of the can 26 within the machine housing 10. In order to avoid axial loading of the can 26 during operation of the

electric machine 2, the latter has the same thermal expansion in the axial direction 4 as the rest of the machine housing 10. The can 26 and the machine housing 10 therefore have the same temperature coefficient.
5 Therefore if the can 26 expands owing to heat being supplied in the axial direction 4, the machine housing 10 also expands, with the result that there is sufficient space (volume) available to the can 26 inside the machine housing 10 for the thermal expansion
10 without said machine housing 10 tilting.

The can 26 is fitted on both sides onto a sleeve 32 made of steel. Each sleeve 32 has a first axial section 34 and an adjoining second axial section 36. The second
15 axial section 36 is aligned with the outside of the can 26, wherein a free region is located between the second axial section 36 and the front faces 30 of the can 26. The first axial section 34 projects into the can 26 and serves as a mounting point for the can 26.

20 In other words, the first axial section 34 bears on the inside of the can 26 at least partially directly or indirectly via a further element. In this way, the can 26 is stabilized with respect to inward buckling. In
25 the illustrated electric motor, a gasket 38 in the form of a so-called O-ring made of rubber is located between the first axial section 34 and the can. A depression, within which the gasket 38 is located, is formed in the first axial section 34.

30 Each sleeve 32 is fitted onto one of the collars 18 and sealed by means of a further gasket 40. The sleeve 32, the gaskets 38, 40 and the can 26 therefore seal the rotor space 22 essentially hermetically with respect to
35 the stator space 26 which is filled with a cooling fluid 42.

While the electric machine 2 is operating, the cooling fluid 42 is at a pressure which is, for example, 3 bar. The can 26 is fabricated in such a way that such a pressure, or else a peak pressure during an overload phase of, in particular, up to 9 bar, does not press the can 26 inward into the rotor space 22 or cause inwardly directed buckles, dents or bends in the can 26. So that the cooling fluid 42 does not penetrate the can 26 itself, the latter is coated on its surface by means of a coating layer 44. The coating layer 44 is composed of a polymer. The cooling fluid 42 is an insulating oil and serves to cool a stator 46 which is arranged inside the stator space 24.

The stator 46 has a laminated core 48 which is composed of a number of laminations stacked one on top of the other. Ducts, through which the cooling fluid 42 can flow, are formed in the laminations, essentially in the axial direction 4. Openings through which a coil package 50 of the stator 46 is inserted are also located inside the laminations. The core package 50 is composed essentially of an electric conductor and has an axial section 52 within which the electric conductor extends mainly parallel to the axial direction 4 and which is located inside the laminated core 48. The axial section 52 is adjoined in the axial direction 4 on both sides by so-called winding heads 54. The electric conductor is turned over inside the winding heads 54 so that the electric conductor is guided again into the axial section 52.

In addition, the laminations of the laminated core 48 have in the center a round cutout within which the can 26 is arranged. The diameter of this cutout is, for example, 150 mm, and the external diameter of the can 26 is, in particular, 0.3 mm less than this. In other words, the external diameter of the can is 149.7 mm, it also being possible for the latter to be larger. The

thermal expansion of the can 26 in the radial direction 6 is matched to the stator 46 and, in particular, to the laminated core 48, in a way which is comparable to the thermal expansion in the axial direction 4, which is matched to the machine housing 10.

While the electric machine 2 is operating, the external diameter of the can 26 does not exceed the diameter of the cutout inside the laminated core 48. This avoids damage to the can 26, which can lead to so-called buckling failure, that is to say the destruction of the can 26 and/or penetration of cooling fluid 42 into the rotor space 22.

The can 26 is arranged inside the laminated core 48 in such a way that the latter extends beyond an electromagnetic effective area 56 between the stator 46 and the rotor 20. The effective area 56 is that region between the stator 46 and the rotor 20 inside which the electromagnetic field generated by said stator 46 and rotor 20 is comparatively large and approximately constant. The length 58 of the effective area 56 corresponds in the illustrated electric machine to the length of the laminated core 48. In other words, the can 26 protrudes in the axial direction 4 on both sides of the laminated core 48.

Fig. 2 shows a perspective view of the can 26 which has a tubular casing 58. The tubular casing 58 is hollow-cylindrical and is composed of a composite fiber material 60 with a fiber 62 which is embedded in a matrix 64. The fiber 62 is composed of glass and the matrix 64 is epoxy resin, with the result that the composite fiber material 60 is a glass-fiber-reinforced plastic. The fiber 62 has a winding angle 66 with respect to the longitudinal direction 28 of the can tube. In other words, when the can 26 is manufactured, for example the fiber 62 is wrapped around a blank or

rolled thereon at a specific angle, specifically the winding angle 66, wherein the blank is cylindrical and the external diameter thereof corresponds essentially to the internal diameter of the can 26. The
5 intermediate spaces between the individual sections of the fiber 62 are filled in by means of the matrix 64. The winding angle 66 is essentially constant over the length of the can 26, but it can vary in the region of the front faces 30 of the can. The winding angle 66 is
10 88° at least over a comparatively large length of the can 26.

The casing thickness 68 of the tubular casing 58 is 1.4 mm. The air gap (annular space) between the stator
15 46 and the rotor 20 can therefore be comparatively small, but, inter alia owing to the selection of the winding angle 66, the can 26 has a comparatively high level of stability and keeps the cooling fluid 42 securely within the stator space 24.

20 The invention is not restricted to the exemplary embodiment described above. Instead, other variants of the invention can also be derived therefrom by a person skilled in the art without departing from the subject
25 matter of the invention. In particular, in addition all the individual features described in relation to the exemplary embodiment can also be combined with one another in another way without departing from the subject matter of the invention.

List of Reference Numbers

2	Electric machine
4	Axial direction
6	Radial direction
8	Rotational axis
10	Machine housing
12	A-side end plate
14	B-side end plate
16	Bearing
18	Collar
20	Rotor
22	Rotor space
24	Stator space
26	Can
28	Longitudinal direction of the can tube
30	Front face
32	Sleeve
34	First axial section
36	Second axial section
38	Gasket
40	Gasket
42	Cooling fluid
44	Coating layer
46	Stator
48	Laminated core
50	Coil package
52	Axial section
54	Winding head
56	Effective area
58	Tubular casing
60	Composite fiber material
62	Fiber
64	Matrix
66	Winding angle
68	Casing thickness

Claims

1. An electric machine (2), in particular an electric motor, having a one-piece can (26) which is arranged
5 between a stator (46) and a rotor (20), and whose tubular casing (58), which is loaded with external pressure by means of a cooling fluid (42) within a machine housing (10), is composed of composite fiber material (60),
10 characterized
in that the casing thickness (68) of the can (26) is less than 2.5 mm and greater than 0.5 mm.
2. The electric machine (2) as claimed in claim 1,
15 characterized
in that the casing thickness (68) is less than 2 mm and greater than 1 mm and, in particular, 1.4 mm.
3. The electric machine (2) as claimed in claim 1 or
20 2,
characterized
in that the can (26) extends in the longitudinal direction (28) of the can tube beyond the electromagnetic effective area (56) between the stator
25 (46) and the rotor (20).
4. The electric machine (2) as claimed in one of claims 1 to 3,
characterized
30 in that the composite fiber material (60) is a glass-fiber-reinforced plastic, and that the winding angle (66) between the longitudinal direction (28) of the can tube and the fiber (62) of the composite fiber material (60) is less than 90° and greater than 70°, in
35 particular greater than 75°.

5. The electric machine (2) as claimed in claim 4,
characterized
in that the winding angle (66) is greater than 80° and
is, in particular, 88°.

5

6. The electric machine (2) as claimed in one of
claims 1 to 5

characterized
in that the tubular casing (58) is coated on the
10 outside by means of a coating layer (44), in particular
by means of a polymer.

7. The electric machine (2) as claimed in one of
claims 1 to 6,

15 characterized
in that the can (26) is not loaded on the front face in
the longitudinal direction (28) of the can tube.

8. The electric machine (2) as claimed in one of
20 claims 1 to 7,

characterized
in that the can (26) is fitted axially onto a sleeve
(32), and in that the sleeve (32) is fitted onto a
collar (18) of an end plate (12, 14) of the machine
25 housing (10).

9. The electric machine (2) as claimed in claim 8,
characterized

in that the sleeve (32) has a first axial section (34)
30 which projects into the can (26) and a second axial
section (36) which adjoins the latter and with which
the can (26) is aligned.

10. The electric machine (2) as claimed in claim 8 or 9,

characterized

5 in that the sleeve (32) is sealed with respect to the can (26) and the collar (18), in each case by means of a gasket (38, 40).

11. The electric machine (2) as claimed in one of claims 1 to 10,

10 characterized

in that the machine housing (10) has axial thermal expansion which is equal to the thermal expansion of the can (26) in the longitudinal direction (28) of the can tube.

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12. The electric machine (2) as claimed in one of claims 1 to 11,

characterized by

20 a power level of less than 1 MW and, in particular, between 50 kW and 500 kW.

13. A can (26) for an electric machine (2) as claimed in one of claims 1 to 12.

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