(12) UK Patent Application (19) GB (11) 2 314 692 (13) A

(43) Date of A Publication 07.01.1998

(21) Application No 9613513.2

(22) Date of Filing 27.06.1996

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(51) INT CL^6
H02K 1/20

(52) UK CL (Edition P)
H2A AKC4 AKC7 AK102 AK210 AK215S AK220S AK302S AK303S AK601S AK602S AK609

(56) Documents Cited
GB 2303745 A **GB 0573773 A** **GB 0453038 A**
GB 0366492 A **GB 0218683 A** **US 5331238 A**

(58) Field of Search
UK CL (Edition O) **H2A AKC7**
INT CL^6 **H02K 1/20 1/32 15/02**

(54) Provision of cooling fins by laminated stator

(57) To provide cooling fins on stator laminations, projections 21 may be formed directly on the lamination so as to produce axial fins when the laminations are assembled. Alternatively, the frame yoke may be asymmetrical 3,4 or 10,11,12 so that when each lamination (or set thereof) is assembled appropriately rotated with respect to adjacent laminations radial fins 7 are formed.

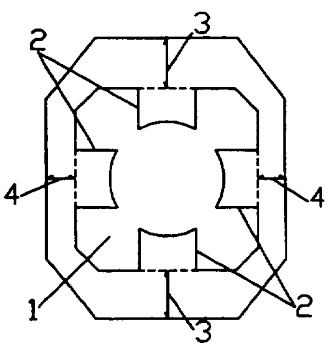

Figure 1

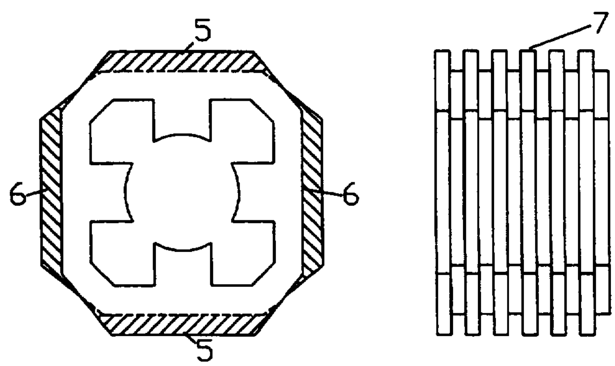

Figure 2

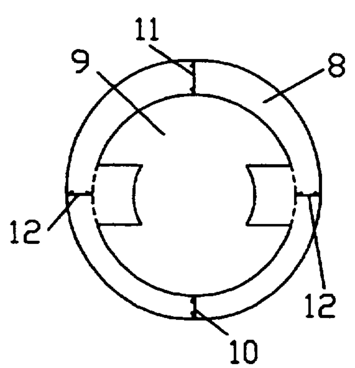

Figure 3

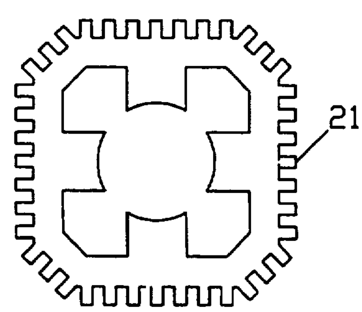

Figure 6

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The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1995

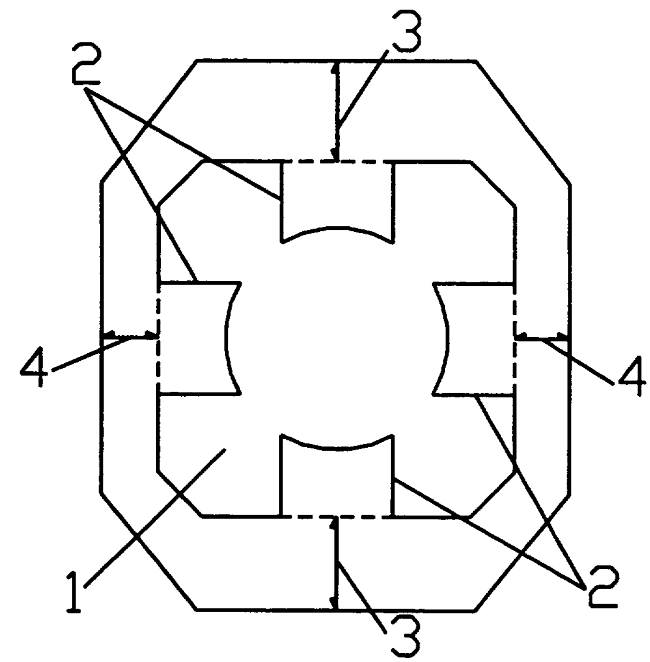

Figure 1

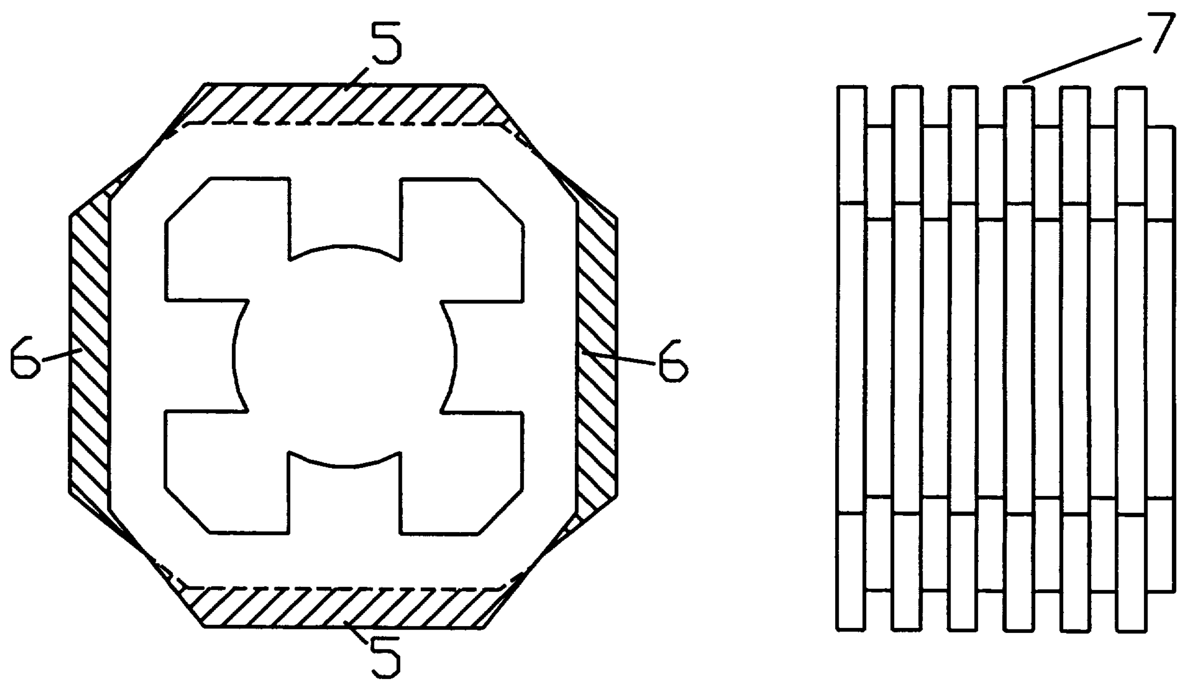

Figure 2

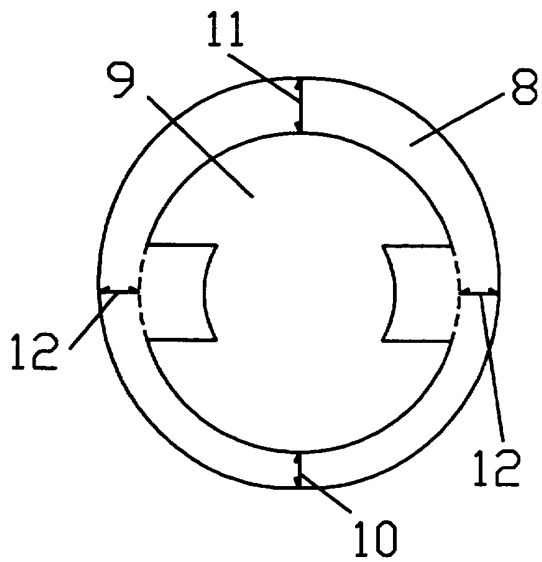

Figure 3

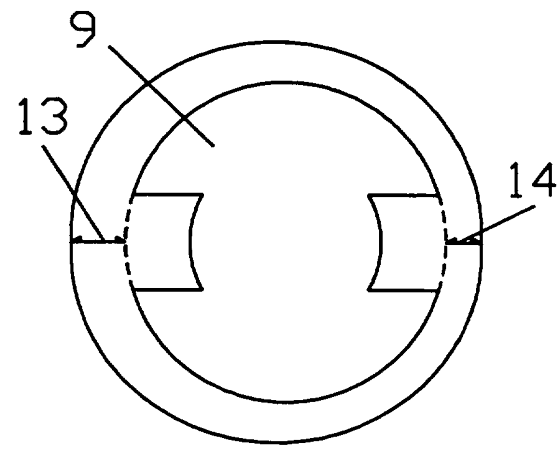

Figure 4

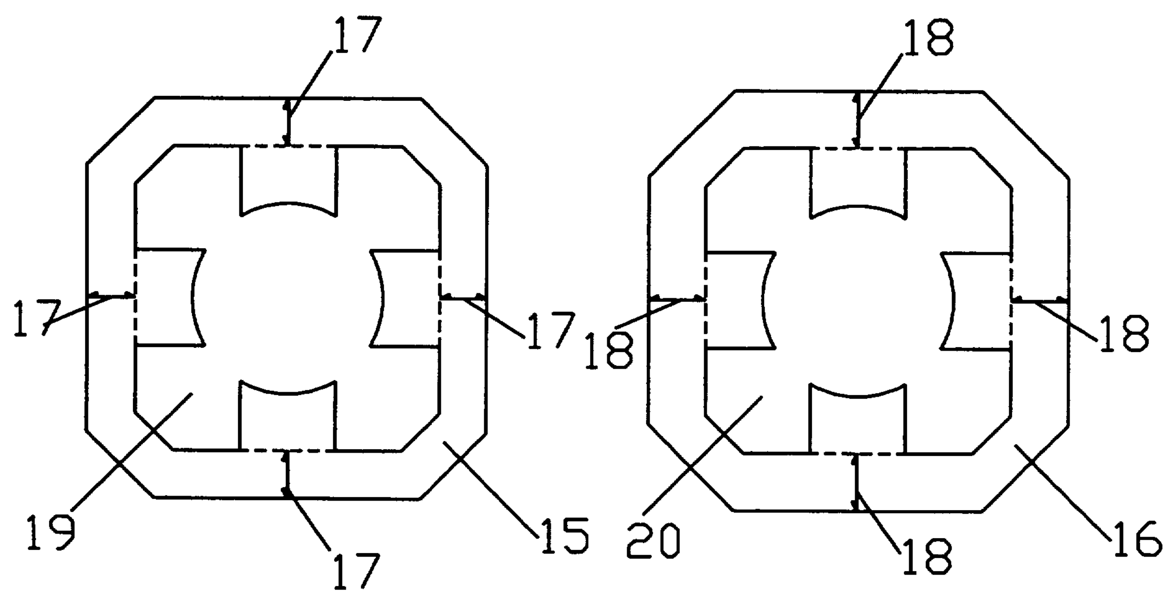

Figure 5

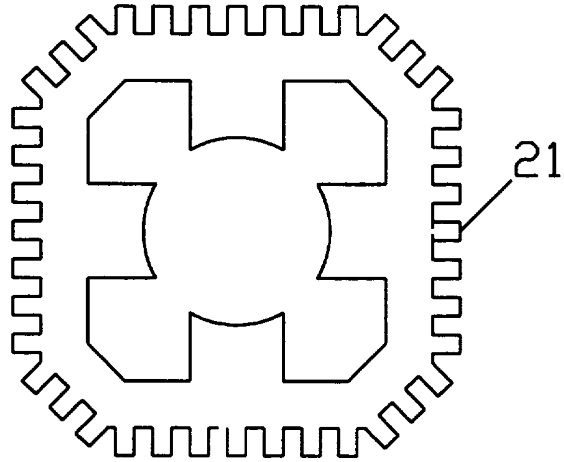

Figure 6

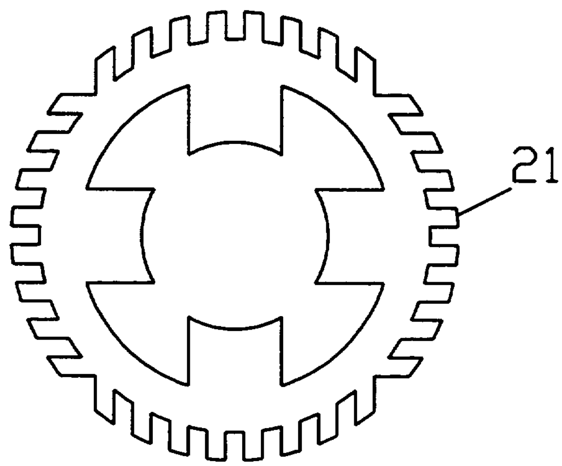

Figure 7

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Provision of Cooling Fins on the Stator of Electromagnetic Machines using Laminated Structures

This invention relates to the provision of cooling fins on electromagnetic machines and is concerned more particularly with using stator lamination designs to increase the exterior dissipative surface area of the machine.

Resistive losses in the windings and iron losses in the core of an electromagnetic device produce thermal energy. The ability of the device to dissipate this thermal energy is fundamental in determining its full-load output capacity. In the presence of these device losses, maximum allowable insulation temperatures limit winding currents to specified levels. A lower insulation temperature is achieved for the same total device losses by improving device cooling. Thus, the improved device cooling permits an increase in the total device losses whilst maintaining the winding insulation temperature within its maximum allowable limit. The increased device losses may follow from an increase in rated winding current which improves force and torque output and hence power output.

In many small rotary machines rated up to ten kilowatts, no cooling fins are provided on the stator. The stator is constructed from radially orientated laminations stacked in the direction of the rotor axis. Thermal dissipation to the ambient surroundings is by convection from the normally smooth surface of the stator casing.

It is an object of the invention to provide a means of utilising the laminated structure of the stator of an electromagnetic machine to provide cooling fins. According to the invention there is a stator of a linear or rotary electromagnetic machine, the stator comprising a stack of laminations, each lamination providing cut-outs suitable for accommodating rotor and an appropriate means of stator excitation, and each stator lamination having a design which, when stator laminations are appropriately stacked, form cooling fins on the exterior surface of the stator which are radially or axially orientated with respect to the rotor or a combination of both.

In order that the invention be more fully understood, reference will now be made to the accompanying drawings, in which:

Figure 1 shows a stator lamination design which is an embodiment of the invention.

Figure 2 shows the manner in which the stator lamination design of Figure 1 is utilised to form cooling fins when the stator laminations are interleaved in groups of one or more and stacked in the axial direction.

Figures 3 and *4* show stator lamination designs, in accordance with the invention, which form radially orientated cooling fins when stacked.

Figure 5 shows a pair of stator lamination designs, in accordance with the invention, which form radially orientated cooling fins when stacked appropriately.

Figures 6 and *7* show stator lamination designs, in accordance with the invention, which form axially orientated cooling fins when stacked.

Figure 1 shows a particular embodiment of the invention. The stator lamination has an interior cut-out, 1, which, in this case, but not exclusively, is for a two-phase switched reluctance machine. The stator poles, 2, are identical in geometry and located at ninety degree intervals around the interior cut-out. The back-iron thicknesses, 3 and 4, are not equal. Groups of one or more stator laminations are orientated at ninety degrees to each other whilst still maintaining the required interior stator pole configuration as shown in Figure 2. The difference in back-iron thicknesses gives areas, 5 and 6, where each group of laminations protrudes from its neighbouring group by a distance given by the difference in the back-iron dimensions. When the stator lamination stack, 7, is comprised of such interleaved groups, the protruding areas provide an extra contact area to the ambient surroundings and thus form cooling fins, which in this case, are radially orientated along the axial length of the stack.

Figure 3 shows a possible embodiment of the invention where, in this case, but not exclusively, one stator lamination is required, 8. The interior cut-out, 9, is configured for a salient, two-pole stator with back-iron thickness, 12, at the stator poles. The back-iron thicknesses, 10 and 11, at the mid-point of the stator limbs differ. Radially orientated cooling fins are formed if groups of one or more laminations are successively rotated through one hundred and eighty degrees and stacked. The back-iron thicknesses, 10 and 11, may be designed such that their average is equal to the back-iron thickness, 12. Figure 4 shows another possible embodiment of the invention. The lamination has an interior cut-out, 9. The back-iron thicknesses, 13 and 14, at the mid-point of the stator poles are different. Groups of one or more laminations, interleaved at one hundred and eighty degrees to each other and stacked, will form radially orientated cooling fins

Figure 5 shows a technique to produce radially orientated cooling fins in accordance with the invention. The two lamination designs, 15 and 16, have back-iron thicknesses, 17 and 18, which are different. The interior cut-outs, 19 and 20, of the lamination designs 15 and 16 are identical. The radial cooling fins are produced by stacking interleaved groups of one or more of each stator lamination design. The set of stator lamination designs, in this case, but not exclusively, the pair of laminations used, can be designed to maintain the average back-iron requirement of the machine when the stator laminations are stacked according to the invention.

In three-phase cylindrical stator machines, the stator lamination shape may be elliptical in form and groups of one or more laminations interleaved, with angular displacements to one another of multiples of sixty electrical degrees, whilst still maintaining the desired stator-pole configuration. Only one lamination design is required.

According to the invention, there are stator lamination designs which form axially orientated cooling fins when stacked appropriately. Figures 6 and 7 show such lamination designs, in accordance with the invention. The teeth, 21, on the exterior edge of the stator lamination will form axially orientated cooling fins when the laminations are stacked. Only one lamination design is necessary to implement this particular technique. The shape and dimensions of the teeth can be designed to maximise surface dissipation with, or without, an axial airflow produced particularly, but not exclusively, by a fan mounted on the rotor shaft. The stator laminations can be designed to provide cooling fins which are optimally orientated with respect to the warm air currents set up by the fins during operation. This includes the possibility of using combinations of axially and radially orientated fins.

The invention can be adopted for alternating and direct current machines in both rotary and linear configurations. This includes cylindrical, non-salient or salient pole machines accommodating any particular number of phase windings and pole-pair numbers in addition to the switched or variable reluctance machine stators.

The invention may be implemented using one stator lamination design. Existing manufacturing techniques can be adopted to produce the lamination geometries. Providing correctly orientated cooling fins is most significant in applications where the machine is totally enclosed and hence conduction is the only cooling method. An advantage is also gained in drives that use fan forced air cooling and where the machine is required to spend significant periods of time at low speeds. During low speed operation, the correctly orientated cooling fins compensate for the reduced air flow from the fan.

In some machines, cooling fins are provided by an external casing surrounding the stator core. The interface between core and case adds an extra thermally resistive component to the cooling circuit. The invention avoids this component by providing a direct interface between stator core and ambient surroundings. For the same frame size, the back-iron of the stator constructed according to the invention will be greater than that using an external casing, if an identical fin geometry is used in both cases. This is a result of the casing being constructed from a steel with low relative permeability. The increased area available for back-iron can be used to increase the outside diameter of the rotor whilst still maintaining the required air-gap length and back-iron. This increases the D^2L product of the machine, improving output power. Conversely, the outside diameter of the machine using fin geometries stamped on the outside edge can be reduced and give the same back-iron area with the same power output but from a machine with a smaller volume.

The exterior surface of the stator may be conformally coated so as to inhibit iron oxidisation and improve surface emissivity.

Claims

1. A stator of a linear or rotary electromagnetic machine, the stator comprising a stack of laminations, each lamination providing cut-outs suitable for accommodating rotor and an appropriate means of stator excitation, and each stator lamination having a design which, when stator laminations are appropriately stacked, form cooling fins on the exterior surface of the stator which are radially or axially orientated with respect to the rotor or a combination of both.

2. A stator of an electromagnetic machine, according to claim 1, where groups of one or more stator laminations are interleaved and stacked to produce radially orientated cooling fins.

3. A stator of an electromagnetic machine, according to claim 1, where a set of stator lamination designs are required to be interleaved and stacked to produce radially orientated cooling fins.

4. A stator of an electromagnetic machine, according to claim 1, where teeth are provided on the exterior edge of each lamination and the laminations stacked to produce axially orientated cooling fins.

5. A stator of an electromagnetic machine, according to claims 1-4, where the stator laminations are designed to maintain the average back-iron requirement of the machine when the stator laminations are stacked accordingly.

6. A stator of an electromagnetic machine, according to claims 1-5, where the stator laminations are designed for a cylindrical or a non-salient or a salient-pole machine accommodating any particular number of phase windings and having any number of pole-pairs.

7. A stator of an electromagnetic machine, according to claims 1-6, where the cooling fins are optimally orientated with respect to warm air currents set up during operation.

8. A stator of a three-phase electromagnetic machine, according to claim 1, where groups of one or more laminations are interleaved with angular displacements to one another of multiples of sixty electrical degrees.

9. A stator of an electromagnetic machine, according to claims 1 and 4, where the shape and dimensions of the teeth are designed to maximise surface dissipation, with or without, an axial airflow.

10. A stator of an electromagnetic machine substantially as described herein with reference to Figures 1 to 7 of the accompanying drawing.

Application No: GB 9613513.2
Claims searched: 1-10
Examiner: John Cockitt
Date of search: 21 August 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H2A [AKC7]

Int Cl (Ed.6): H02K [15/02, 01/20, 01/32]

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2303745A	AISIN - see rotated laminations	1-9 at least
X	GB0573773A	STEVENS - see asymmetric laminations rotated to provide cooling fins	1-9 at least
X	GB0453038A	ALDEN - see axial channels defined by flutes	1-9 at least
X	GB0366492A	CONSTRUCTIONS - see rotated laminate sets	1-9 at least
X	GB0218683A	EHRMANN - see rotatable laminae with projection	1-9 at least
X	US5331238A	SUNDSTRAND - see laminate cooling fins	1-9 at least

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Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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