

(21) Application No: 2218478.2

(22) Date of Filing: 08.12.2022

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(51) INT CL:
H02K 3/28 (2006.01) **H02K 3/50** (2006.01)
H02K 5/22 (2006.01)

(56) Documents Cited:
JP 2008029127 A **US 20200292055 A1**
US 20090127948 A1

(58) Field of Search:
INT CL **H02K**
Other: **WPI, EPODOC, Patent Fulltext, INTERNET,**
INSPEC, XPI3E

(54) Title of the Invention: **A high-speed electrical machine and a stator**
Abstract Title: **High speed electrical machine with star point outside of bearing span**

(57) A high-speed electrical machine 100 comprises a housing (201, fig.2), bearings (205, fig.2), and a stator 100 located within the housing. The stator has cables 115 extending from a body portion that are connected at a star point 120 located outside of the bearing span (B, fig.2) and within the housing. The cables that connect at the star point may project from an end face 110a of the body portion. Additional cables 125 may project from this same end face and may be alternating current power cables. The star point cables may have a portion projecting in a direction parallel and/or perpendicular to the longitudinal axis L of the body portion. The cables may be generally straight or generally curved with the centre of the curvature of the cables located on the longitudinal axis of the body. The star point may abut a bearing or the stator and one of the cables may extend past a bearing. The body may comprise a cooling jacket. The star point may be located within a star point housing. The electrical machine may be a low voltage electrical machine. The electrical machine may be a turbocharger and may be mounted on a vehicle.

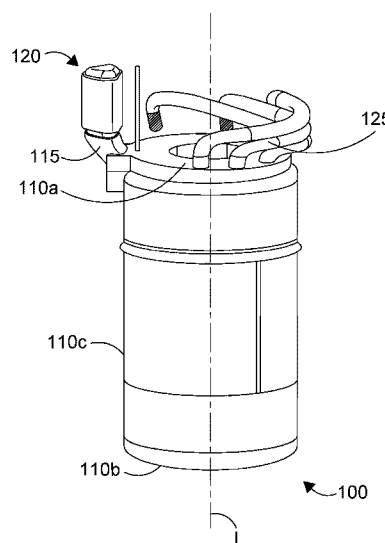


FIG. 1

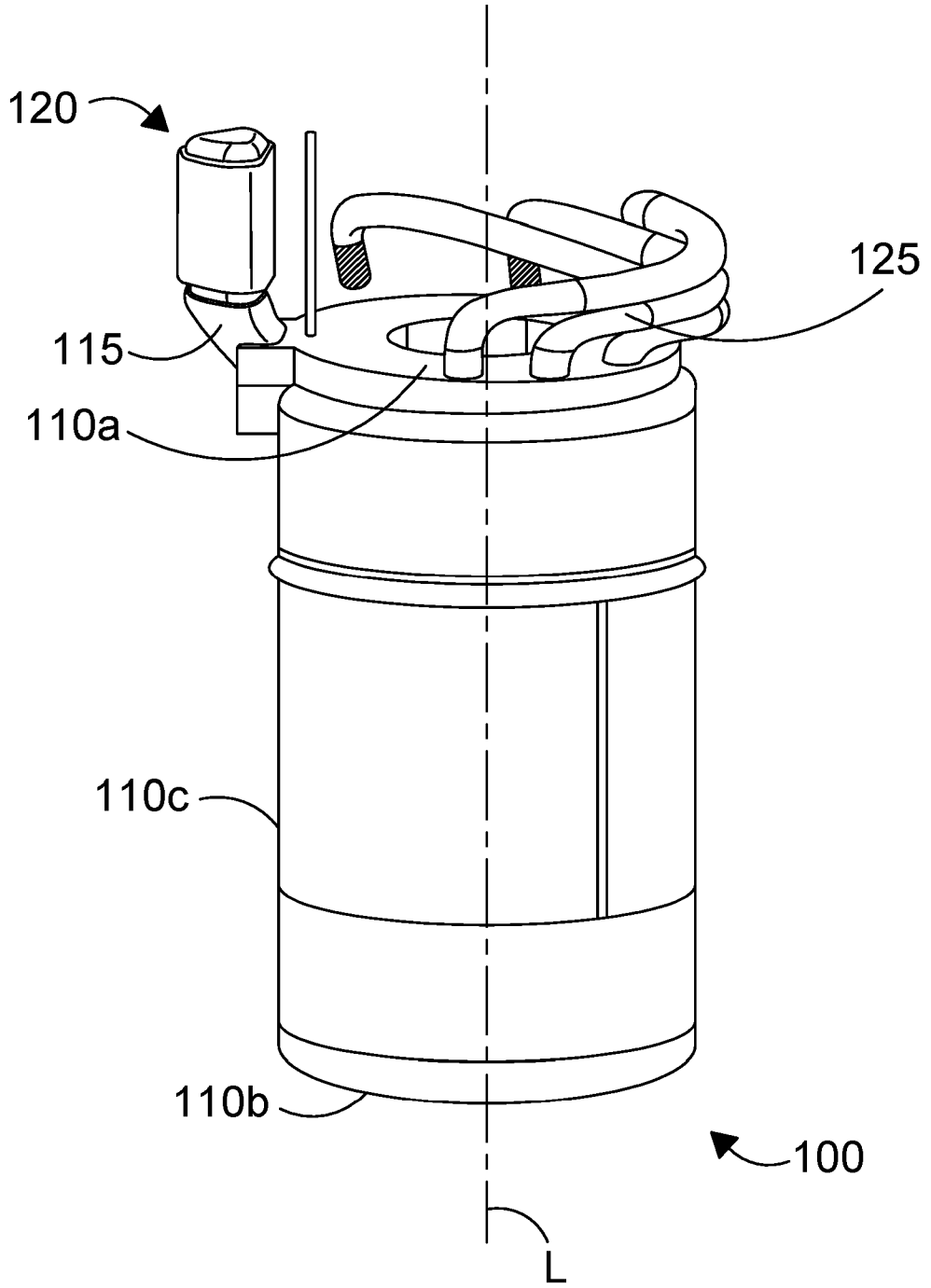


FIG. 1

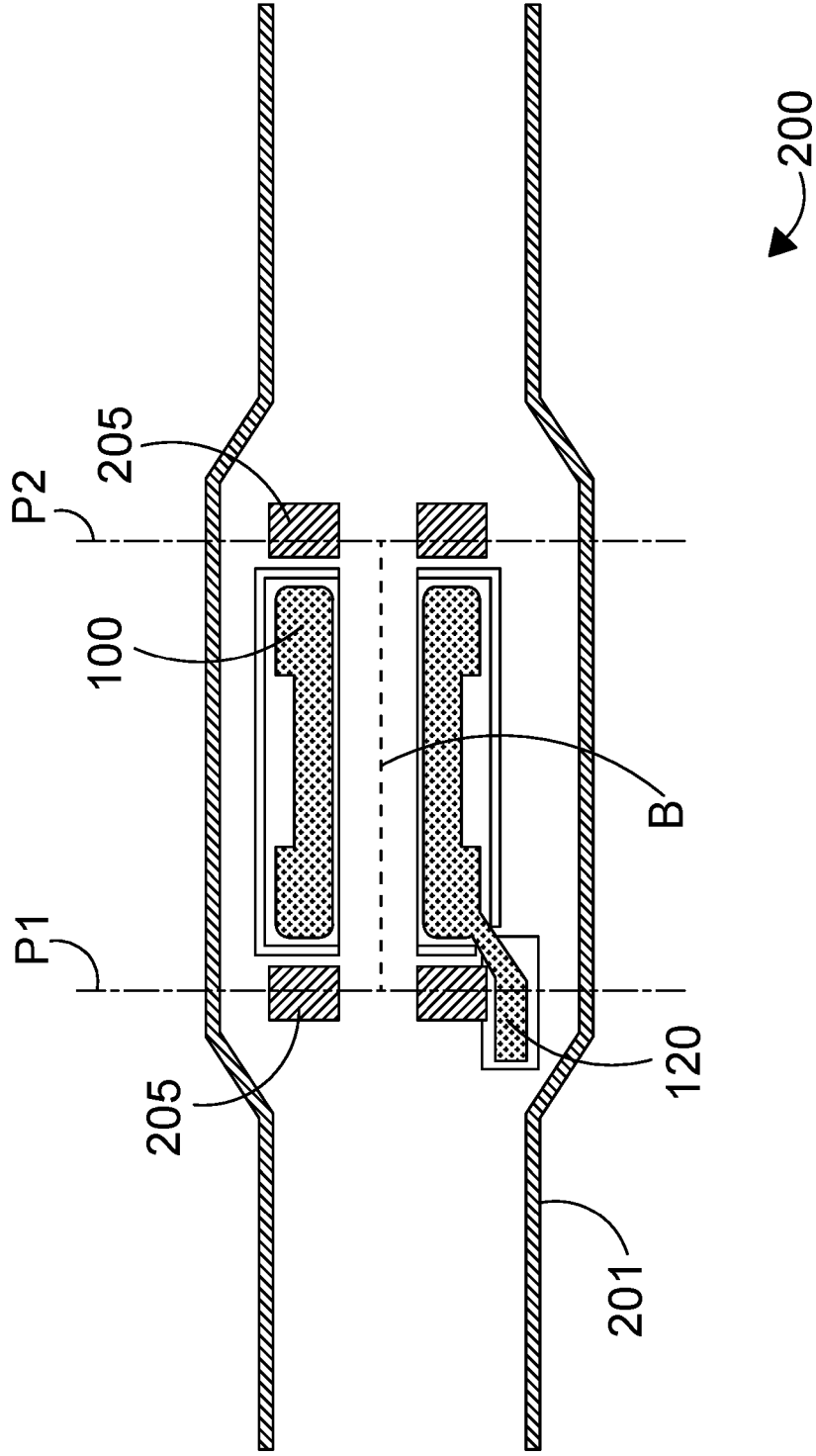


FIG. 2

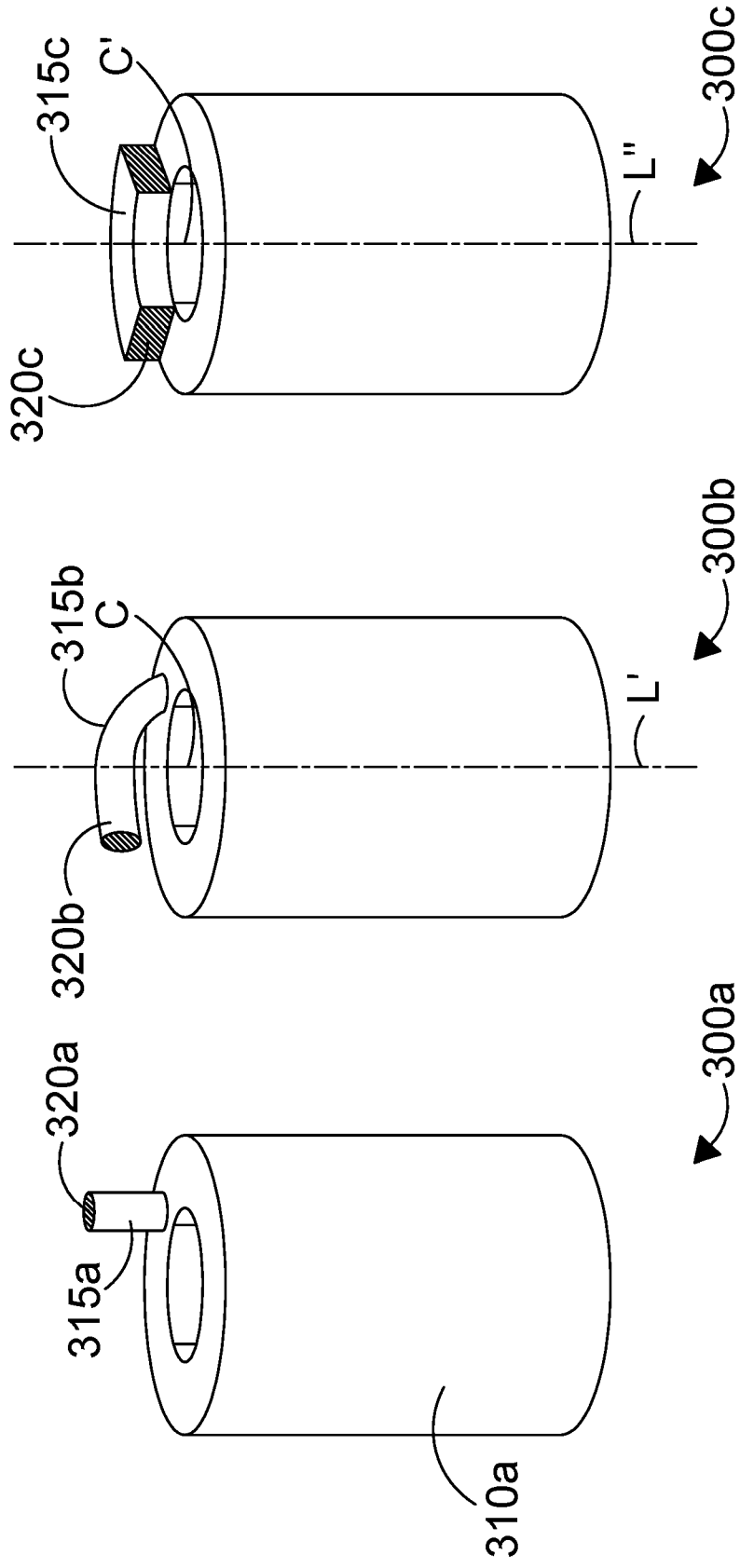


FIG. 3A

FIG. 3B

FIG. 3C

A HIGH-SPEED ELECTRICAL MACHINE AND A STATOR

Field of the invention

5 The present invention relates to a high-speed electrical machine and a stator for use in a high-speed electrical machine.

Background to the invention

10 A star point or star connection is a common junction or connection point of a plurality of cables extending from or in an electrical machine. The star point commons the loads in the circuit. Such a feature is advantageous in polyphase electrical systems and unbalanced electrical systems, wherein the load on each phase may not be equal and it is desirable to spread the load between multiple circuits or devices. An example of a star point is a Wye connection
15 used in three-phase electrical machines.

Electrical machines, such as electric motors and electric generators comprise bearings having a bearing span. The bearing span is influenced by the length of the electrical machine, and consequently has an effect on the rotordynamic performance of the electrical machine.

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As the bearing span decreases, there is an increase in the resonant frequency of the shaft of the electrical machine, such as the central shaft of an electric motor or turbogenerator. It is desirable to operate below the shaft resonant frequency and, therefore, advantageous to minimise the bearing span.

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However, the cables connected at a star point are often a fixed size and cannot be scaled-down. Such a problem is particularly prevalent in high-speed electrical devices that require larger cables relative to the size of the machine compared to low-speed machines. This problem is further compounded in low-voltage applications wherein the cross-sectional area
30 of the cable is inversely proportional to the reduction in the required transmitted voltage.

Objects and aspects of the present invention seek to alleviate at least these problems with the prior art.

35 **Summary of the Invention**

According to a first aspect of the present invention, there is provided a high-speed electrical machine comprising a housing and a stator located within the housing, the stator comprising a body portion, a plurality of cables extending from the body portion, the plurality of cables connected at a star point; wherein the high-speed electrical machine comprises bearings, the bearings having a bearing span, wherein the star point is located outside of the bearing span and within the housing.

It is understood that high-speed electrical machines are those which exceed 15,000 rpm or 500 Hz.

It is understood that a star point is a common junction or connection point of a plurality of cables extending from an electrical machine, such as a Wye connection used in three-phase electrical machines. Application in polyphase electrical machines, including six-phase machines, is also envisaged.

When the star point is located outside the bearing span, the length of the bearing span can be reduced. The reduction in bearing span increases the resonant frequency of any shaft within the electrical machine, such as the central shaft of an electrical motor. By increasing the resonant frequency of the shaft, the electrical machine can operate at higher frequencies before the resonant frequency is reached. Such a benefit is advantageous in improving the, operating range, power, safety and rotordynamic properties of the electrical machine.

In addition, such a change maximises the power density of the electrical machine. Maximising the power density of the electrical machine allows a more powerful machine to be provided for a given size or fixed power output. In this way, a smaller machine is capable of providing greater power given the high power density capabilities. Such a feature is highly advantageous when space constraints are an important parameter in the electrical machine application. For example, in electrical turbomachines and mobile or stationary powertrains, such as internal combustion engines and hydrogen fuel cells.

Further, when the star point is located outside the bearing span, the ratio of the active length of the electrical machine to the non-active length of the electrical machine end turn length is maximised. In this way, the power density and consequently the power provided by the electrical machine is increased. For example, active length may be the active length of a stator of the electrical machine and the non-active length may be the non-active end portions of the stator.

Additionally, there is provided improved access to the star point, such as to fuse, crimp, braze or solder the plurality of cables connecting at the star point.

5 Preferably, at least one of the plurality of cables that connect at a star point projects from a point adjacent an end of the body portion.

10 Preferably, at least one of the plurality of cables that connect at a star point projects from one of the end faces of the body portion. Preferably, at least one additional cable projects from the end face from which at least one of the plurality of cables that connect at a star point projects. Preferably, the additional cable is an alternating current power cable.

15 Preferably, a portion of the plurality of cables that connect at a star point projects in a direction parallel to the longitudinal axis of the body portion. Alternatively, or additionally, a portion of the plurality of cables that connect at a star point projects in a direction perpendicular to the longitudinal axis of the body portion. In this way, a first portion of the plurality of cables that connect at a star point projects in a direction parallel to the longitudinal axis of the body portion and a second portion of the plurality of cables that connect at a star point projects in a direction perpendicular to the longitudinal axis of the body portion.

20 Preferably, in use, the star point is located below the bearings. More preferably, the star point is located directly below at least one bearing. Alternatively, the electrical machine may be configured such that, in use, the star point is closer to the ground than at least one bearing. Such a feature is particularly advantageous in oil fed bearings, therein the plurality of cables connected at a star point are located in the oil drain area which will cool the cables. Thermal management of the cables is particularly advantageous in power dense machines.

30 Preferably, the cables within the plurality of cables that connect at a star point are generally straight. Alternatively, the cables within the plurality of cables that connect at a star point are generally curved. Preferably, the centre of curvature of the plurality of cables that connect at a star point is located on the longitudinal axis of the body portion.

Preferably, the centre of curvature of the plurality of cables that connect at a star point is located on the longitudinal axis of the body portion.

35 Preferably, the star point is located adjacent to at least one bearing. Preferably, the star point is proximate at least one bearing. Preferably, star point abuts at least one bearing.

Each of these embodiments may be preferable as they allow the bearing span to be reduced and a concomitant reduction in the overall size of the high-speed electrical machine.

5 Preferably, at least one of the plurality of cables that connect at a star point extends from the body portion past at least one bearing. More preferably, each of the plurality of cables that connect at a star point extends from the body portion past at least one bearing.

10 Preferably, the star point and the stator are located on opposing sides of a plane defined by the at least one bearing. The plane of the bearing may be defined as the plane within which the various portions of the bearing rotate relative to one another. For example, the plane of a bearing may be considered to be the plane within which the rolling elements move within the races.

Preferably, the star point is located adjacent to the stator. Preferably, the star point is proximate the stator. Preferably, the star point abuts the stator.

15 Preferably, the high-speed electrical machine is a low voltage electrical machine. Preferably a low voltage electrical machine operates at 200V or less. More preferably, a low voltage electrical machine operates at 60V or less. Most preferably, a low voltage electrical machine operates at 48V or less.

20 Preferably, the plurality of cables that connect at a star point is located within the cross section defined by the outer perimeter of the body portion. In this way, the maximum width of the stator is the width of the body portion or housing. As such, the size of the stator, and the electrical machine, is minimised which is advantageous in applications wherein reducing the footprint of the electrical machine is critical.

25 Preferably, the body portion comprises a cooling jacket. Preferably, the star point is located within a star point housing.

30 Preferably, the body portion is cylindrical, the cylindrical body portion comprising two substantially parallel end faces connected by a curved face.

Where the body portion of the stator is cylindrical, it may be preferable for the star point to be proximate an end face. Where the body portion of the stator is cylindrical, it may be preferable for the star point to abut an end face. Where the body portion of the stator is cylindrical, it may be preferable for the star point to be adjacent to an end face.

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Preferably, the high speed electrical machine is a turbomachine. More preferably, the high-speed electrical machine is an electric turbocharger. Preferably, the high-speed electrical machine is mounted on a vehicle. More preferably, the vehicle is a lorry or truck. Most preferably, the high-speed electrical machine is a vehicle mounted electric turbocharger.

5 Even more preferably, the high-speed electrical machine operates in a 48 V environment.

According to a second aspect of the present invention, there is provided a stator for use in the electrical machine as previously described.

10 Detailed Description

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

15 Figure 1 depicts a perspective view of a stator in accordance with the present invention;

Figure 2 depicts an interior view of an electrical machine in accordance with the present claimed invention; and

20 Figures 3A-3B depict three further embodiments of a stator in accordance with the present invention.

With reference to Figure 1, there is illustrated a stator for a high-speed electrical machine 100 comprising a cylindrical body portion. The cylindrical body portion comprises a first end face
25 110a and an opposing second end face 110b. The cylindrical body portion further comprises a curved face 110c connecting the first end face 110a and the second end face 110b.

A plurality of copper cables 115 extend from the stator 100 and project through the first end face 110a of the cylindrical body portion. The plurality of cables 115 connect at a star point or
30 star connection 120 which is located outside or external to the cylindrical body portion.

A plurality of additional cables 125 project from the first end face 110a of the cylindrical body portion. The plurality of additional cables 125 comprises a plurality of alternating current (AC) power cables. In this way, the plurality of copper cables 115 and plurality of additional cables
35 125 extend from the same end face of the cylindrical body portion.

The portion of the plurality of cables 115 adjacent the star point 120 are substantially straight and project in a direction parallel to the longitudinal axis L of the cylindrical body portion. The star point 120 is located within a star point housing, which encases and protects the star point 120.

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With reference to Figure 2, an electrical machine 200 comprising the stator 100 is illustrated. The electrical machine 200 comprises a housing 201 and further comprises a pair of bearings 205. Each bearing has a plane, P1 and P2, with the distance between the bearings 205 being the bearing span B. As can be seen in Figure 2 the star point 120 is located outside of the bearing span B, and on the opposite side of the bearing plane P1 to the stator. Additionally, the star point 120 is located adjacent to bearing 205, and proximate the stator 100. Additionally, the star point 120 is located within the housing 210 of the electrical machine.

10

It can also be seen from Figure 2 that, in use, the star point 120 is located below the bearings 205. In the embodiment depicted in Figure 2, the star point is positioned directly below a bearing 205.

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Figure 3A depicts a second embodiment of a stator 300a comprising a substantially straight plurality of cables 315a. The plurality of cables 315a that connect at a star point 320a is located within the cross section defined by the outer perimeter of the body portion of the stator 300a. In this way, the width of the electrical machine 300a is limited to the maximum width of the cylindrical body portion 310a. As can be seen in Figure 3a, the star point 320a is located proximate the stator 300a.

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Figure 3B depicts a third embodiment of a stator 300b comprising a generally curved plurality of cables 315b connect at a star point 320b. The centre of curvature C of the plurality of cables 315b is located on the longitudinal axis L' of the cylindrical body portion. The star point 320b and the plurality of cables 315b are located within a star point housing. the star point 320b is located proximate the stator 300b.

25

30

Figure 3C similarly depicts a fifth embodiment of a stator 300c comprising a generally curved plurality of cables 315c connect at a star point 320c. The centre of curvature C' of the plurality of cables 315c is located on the longitudinal axis L'' of the cylindrical body portion. The star point 320b and the plurality of cables 315b are located within a star point housing. Once more, the star point 320c is located proximate and abutting the stator 300c, more specifically an end face of the cylindrical body portion.

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Further embodiments within the scope of the present invention may be envisaged that have not been described above, for example, there may be different shapes and/or relative dimensions of the plurality of cables, star point and star point housing. The invention is not limited to the specific examples or structures illustrated, a greater number of components than are illustrated in the Figures could be used, for example.

5

CLAIMS

1. A high-speed electrical machine comprising a housing and a stator located within the housing,
5 the stator comprising
 a body portion,
 a plurality of cables extending from the body portion,
 the plurality of cables connected at a star point;
wherein the high-speed high-speed electrical machine comprises bearings, the
10 bearings having a bearing span, wherein the star point is located outside of the
bearing span and within the housing.
2. The high-speed electrical machine of claim 1, wherein at least one of the plurality of
15 cables that connect at a star point projects from a point adjacent an end of the body
portion.
3. The high-speed electrical machine of claim 1 or claim 2, wherein at least one of the
20 plurality of cables that connect at a star point projects from an end face of the body
portion.
4. The high-speed electrical machine of claim 3, wherein at least one additional cable
projects from the end face from which at least one of the plurality of cables that
connect at a star point projects.
- 25 5. The high-speed electrical machine of claim 4, wherein the additional cable is an
alternating current power cable.
6. The high-speed electrical machine of any one preceding claim, wherein a portion of
30 the plurality of cables that connect at a star point projects in a direction parallel to the
longitudinal axis of the body portion.
7. The high-speed electrical machine of any one preceding claim, wherein a portion of
35 the plurality of cables that connect at a star point projects in a direction perpendicular
to the longitudinal axis of the body portion.
8. The high-speed electrical machine of any one preceding claim wherein, in use, the
star point is located below the bearings.

9. The high-speed electrical machine of any one preceding claim, wherein the cables within the plurality of cables that connect at a star point are generally straight.
- 5 10. The high-speed electrical machine of claims 1 to 8, wherein the cables within the plurality of cables that connect at a star point are generally curved.
- 10 11. The high-speed electrical machine of claim 10, wherein the centre of curvature of the plurality of cables that connect at a star point is located on the longitudinal axis of the body portion.
12. The high-speedhigh-speed electrical machine of any one preceding claim, wherein the star point is located adjacent to at least one bearings.
- 15 13. The high-speed electrical machine of any one preceding claim, wherein the star point is proximate at least one bearing.
- 20 14. The high-speed electrical machine of any one preceding claim, wherein the star point abuts at least one bearing.
- 25 15. The high-speed electrical machine of any one preceding claim, wherein at least one of the plurality of cables that connect at a star point extends from the body portion past at least one bearing.
- 30 16. The high-speed electrical machine of claim 15, wherein each of the plurality of cables that connect at a star point extends from the body portion past at least one bearing.
- 35 17. The high-speed electrical machine of claim 14 or claim 16, wherein the star point and the stator are located on opposing sides of a plane defined by the at least one bearing.
18. The high-speed electrical machine of any one preceding claim, wherein the star point is located adjacent to the stator.
19. The high-speed electrical machine of any one preceding claim, wherein the star point is proximate the stator.

20. The high-speed electric machine of any one preceding claim, wherein the star point abuts the stator.
- 5 21. The high-speed electrical machine of any one preceding claim, wherein the electrical machine is a low voltage electrical machine.
22. The high-speed electrical machine of any one preceding claim, wherein the body portion comprises a cooling jacket.
- 10 23. The high-speed electrical machine of any one preceding claim, wherein the star point is located within a star point housing.
- 15 24. The high-speed electrical machine of any one preceding claim, wherein the body portion is cylindrical, the cylindrical body portion comprising two substantially parallel end faces connected by a curved face.
25. The high-speed electrical machine of any one preceding claim, wherein the high-speed electrical machine is a turbocharger.
- 20 26. The high-speed electrical machine of any one preceding claim, wherein the high-speed electrical machine is mounted on a vehicle.
27. A stator for use in the high-speed electrical machine of any one preceding claim.
- 25



Application No: GB2218478.2

Examiner: Jonathan Marlow

Claims searched: 1-27

Date of search: 11 May 2023

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-27	JP 2008029127 A (TOYOTA MOTOR CORP) Figures 1-3 and paragraph [0014].
X	1-27	US 2020/0292055 A1 (ENDO et al.) Figure 1 and paragraphs [0046], [0076], [0100].
X	1-27	US 2009/0127948 A1 (SHIMIZU et al.) Figures 1, 3, 5 and 14.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

H02K

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC, Patent Fulltext, INTERNET, INSPEC, XPI3E

International Classification:

Subclass	Subgroup	Valid From
H02K	0003/28	01/01/2006
H02K	0003/50	01/01/2006
H02K	0005/22	01/01/2006