



US 20180170565A1

(19) **United States**

(12) **Patent Application Publication**  
**STEINWANDEL et al.**

(10) **Pub. No.: US 2018/0170565 A1**

(43) **Pub. Date: Jun. 21, 2018**

(54) **AIRCRAFT DRIVE DEVICE AND AIRCRAFT PROVIDED WITH A DRIVE DEVICE**

*H05K 9/00* (2006.01)

*H02K 7/08* (2006.01)

*H02K 11/26* (2006.01)

(71) Applicant: **Airbus Defence and Space GmbH**,  
Taufkirchen (DE)

(52) **U.S. Cl.**

CPC ..... *B64D 27/24* (2013.01); *B64D 45/02*  
(2013.01); *B64D 35/00* (2013.01); *H02K*  
*7/083* (2013.01); *H02K 11/26* (2016.01);  
*H05K 9/0047* (2013.01)

(72) Inventors: **Jürgen STEINWANDEL**,  
Uhdlingen-Mühlhofen (DE); **Michael**  
**HOFMANN**, Neubiberg (DE); **Michael**  
**JUDAS**, München (DE)

(57) **ABSTRACT**

(21) Appl. No.: **15/850,350**

An aircraft drive device (10) for creating propulsion and/or lift of an aircraft, the drive device comprising a rotating shaft (12), a rotating shaft bearing (14, 16), a rotating shaft drive machine (18) for rotationally driving the rotating shaft (12), and a housing (20), wherein the rotating shaft bearing (14,16) and the rotating shaft drive device (18) are arranged in an interior of the housing (44) and the rotating shaft (12) protrudes to the outside of the housing (20) through a housing opening (42) of the housing (20), wherein in the region of the housing opening (42) an overvoltage arrester device (52) is arranged which is designed for diverting an overvoltage present at the rotating shaft (12).

(22) Filed: **Dec. 21, 2017**

(30) **Foreign Application Priority Data**

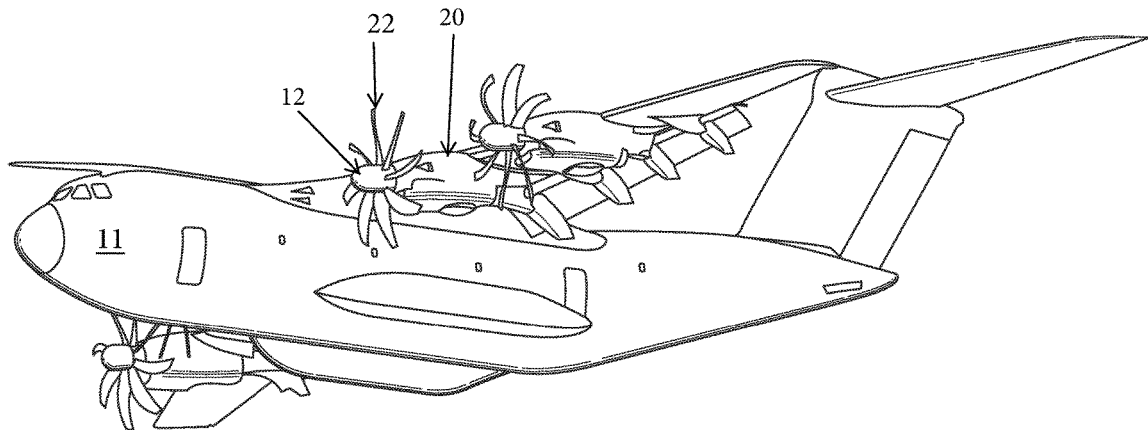
Dec. 21, 2016 (EP) ..... 16205978.6

**Publication Classification**

(51) **Int. Cl.**

*B64D 27/24* (2006.01)

*B64D 45/02* (2006.01)



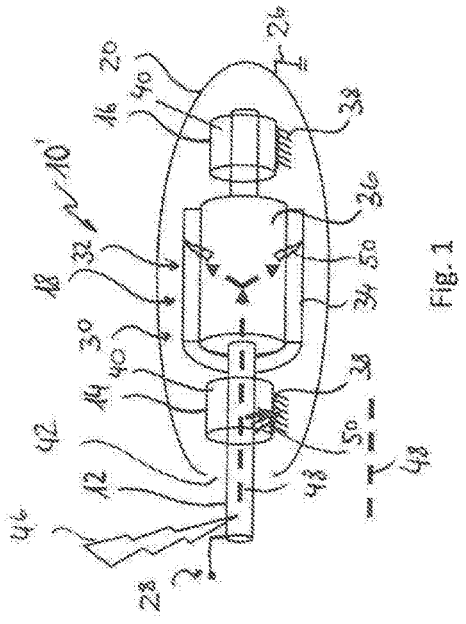


FIG. 1

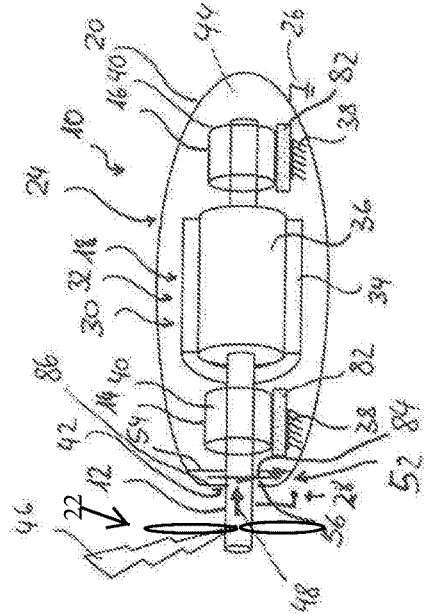


FIG. 2

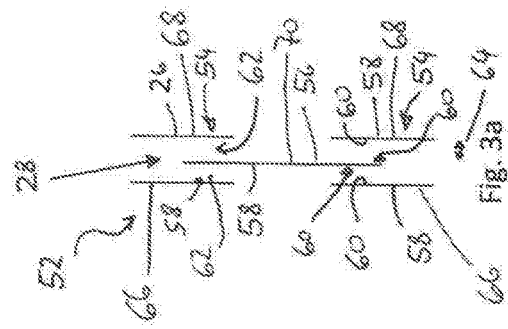


FIG. 3a

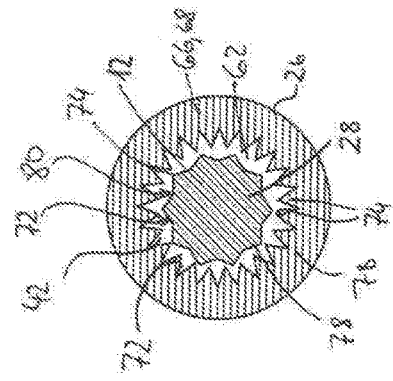


FIG. 3b

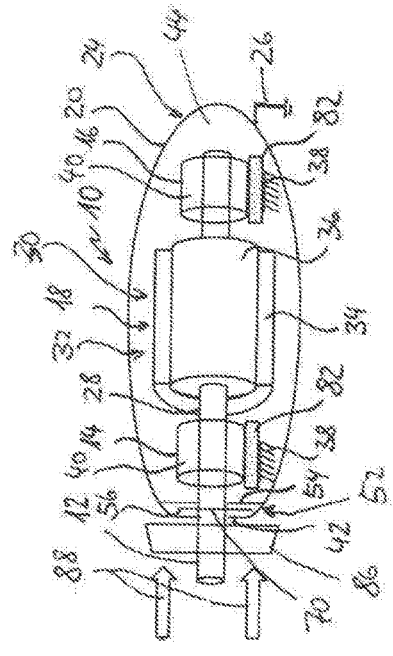


FIG. 4

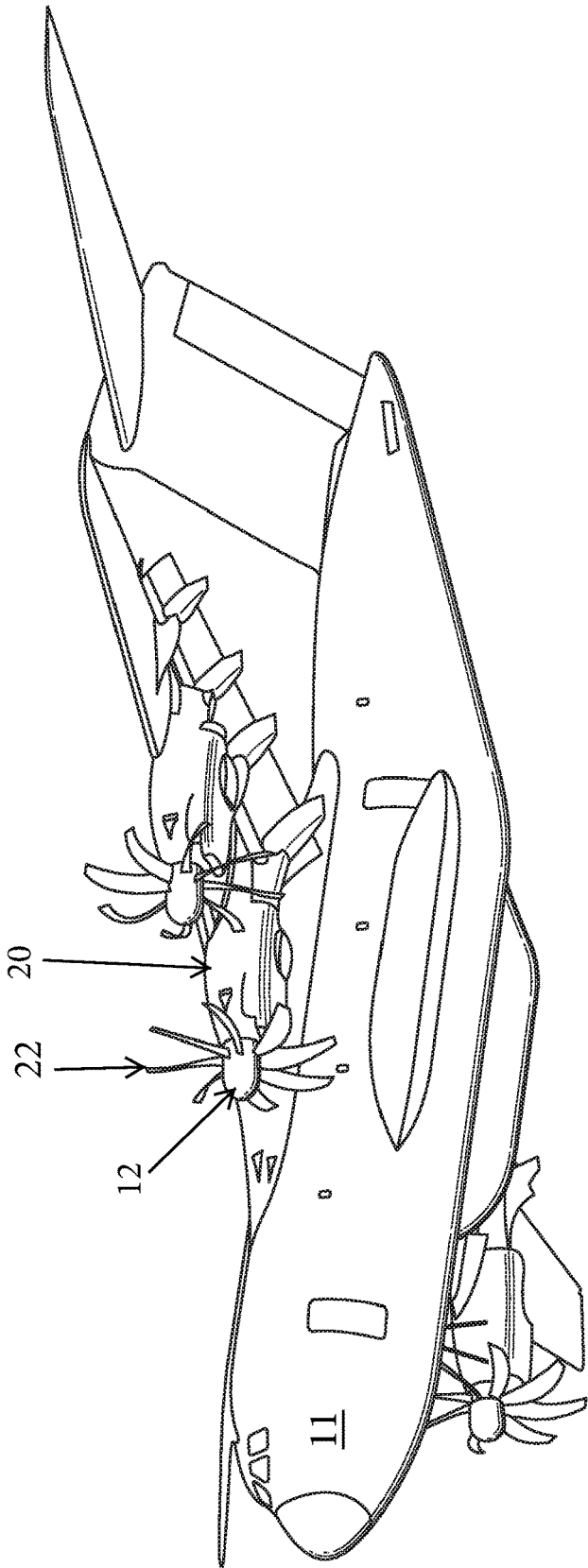


Fig. 5

**AIRCRAFT DRIVE DEVICE AND AIRCRAFT PROVIDED WITH A DRIVE DEVICE**

## RELATED APPLICATION

**[0001]** This application claims priority to European Patent Application 16205978.6 filed Dec. 21, 2016, the entirety of which is incorporated by reference.

## BACKGROUND OF THE INVENTION

**[0002]** The invention relates to an aircraft drive device for creating propulsion and/or lift of an aircraft, the drive device having a rotating shaft protruding from a housing. The invention also relates to an aircraft provided with the drive device.

**[0003]** Examples of such aircraft drive devices are disclosed in DE 10 2005 006 511 A1, DE 10 2013 109 392 A1 or DE 10 2010 021 024 B1.

**[0004]** Currently, aircraft equipped with electrically driven propellers are no longer the subject of theoretical considerations, but rather are at the beginning of concrete developments for different use cases, see the above-mentioned documents and also DE 10 2013 101 602 A1 and DE 10 2006 056 356 A1.

## SUMMARY OF THE INVENTION

**[0005]** The invention may be embodied to improve an aircraft drive device for creating propulsion and/or lift of an aircraft and having a rotating shaft protruding from a housing with regard to operational safety at various weather conditions, with little constructional effort.

**[0006]** The invention, in one embodiment, is an aircraft comprising a drive device of the type disclosed herein.

**[0007]** According to one aspect, the invention provides an aircraft drive device for creating propulsion and/or lift of an aircraft, the drive device comprising a rotating shaft, a rotating shaft bearing, a rotating shaft drive machine for rotationally driving said rotating shaft, and a housing, such as a nacelle, wherein the rotating shaft bearing and the rotating shaft drive machine are arranged in the interior of the housing and the rotating shaft protrudes to the outside of the housing through a housing opening of the housing, wherein in the region of the housing opening an overvoltage arrester device is arranged which is designed for diverting an overvoltage present at the rotating shaft.

**[0008]** At least a region of the rotating shaft may be at an electrical potential of the rotating shaft and at least a region of the housing is at an electrical potential of the housing and that an overvoltage arrester device is designed for diverting an overvoltage from the rotating shaft potential to the housing potential. Alternatively, the overvoltage arrester device can also divert the overvoltage to other potentials on the aircraft, such as to ground or to the potential of an electrical discharge and distribution device.

**[0009]** The rotating shaft drive machine may be an electric machine, such as an electric motor having a rotor and a stator.

**[0010]** The aircraft drive device may comprise an electrically driven propeller.

**[0011]** The propeller may be arranged on the part of the rotating shaft protruding from the housing.

**[0012]** A first rotating shaft bearing and a second rotating shaft bearing may be provided.

**[0013]** The housing may be designed for providing lightning protection for the rotating shaft drive machine itself.

**[0014]** The housing may create a Faraday cage.

**[0015]** The overvoltage arrester device may comprise a stationary electrode element being at a potential to which the diversion shall be made, such as the housing potential or the ground, and a rotatable electrode element being at a rotating shaft potential, wherein for a contactless voltage transfer of over-voltages, said electrode elements are spaced by a gap.

**[0016]** At least one of the electrode elements may be ring-shaped.

**[0017]** It is preferred that at least one of the electrode elements comprises a first ring and a second ring between which the other electrode element is received.

**[0018]** The electrode elements may comprise substantially parallel opposing electrode surfaces between which said gap is formed.

**[0019]** At least one of the electrode elements may comprise an electric arc ignition element for igniting a plasma channel for the purpose of transferring the overvoltage.

**[0020]** At least one of the electrode elements may be provided with a tip formed of a conductive material.

**[0021]** At least one of the electrode elements may be provided with a coating in which spikes formed of conducting particles and/or polarizing particles are provided.

**[0022]** The gap may represent the smallest distance between the rotating shaft potential and the housing potential. The gap may have a gap distance in the range of 0.1  $\mu\text{m}$  to 10 mm, preferably in the range of 0.01 mm to 5 mm.

**[0023]** The rotating shaft bearing may comprise a stationary bearing element and a rotatable bearing element and an electrical insulation for electrically insulating said stationary bearing element from said rotatable bearing element.

**[0024]** At least a region of the rotating shaft and/or the housing may be provided with a lightning protection coating. The lightning protection coating may comprise an electrically conductive layer or an electrically conductive grid. The lightning protection coating may be provided with electrically polarizable particles, electrically conductive spiked particles, or with electrically polarizable particles in a dielectric matrix.

**[0025]** The lightning protection coating may be a coating with electrically conductive spiked particles in a dielectric matrix or a coating with ignition elements for igniting an electric arc.

**[0026]** The overvoltage arrester device may comprise a wind deflector element for protecting the electric arc. The overvoltage arrester device may enable the diversion of an overvoltage between the rotating rotary shaft and a stationary part. The overvoltage arrester device may be designed in such a way that the diversion of the overvoltage takes place in a contactless manner by electric flashover and an electric arc. The overvoltage arrester device may have a field-boosting geometry so that the flashover preferably occurs at the intended location. The overvoltage arrester device may be provided with a field-boosting coating so that the flashover preferably occurs at the intended location.

**[0027]** The term "a/an" used in the present disclosure, particularly in the attached claims, is an indefinite article rather than a numeral and is intended to express that a single one of the items so designated is provided, but does not exclude that there may be present more than one of those items.

**[0028]** Some advantages and specific features of the disclosed embodiments of the invention will be described in more detail in the following.

**[0029]** The invention may be configured to provide lightning protection of electrically driven propellers.

**[0030]** The invention may be configured for an aircraft drive device equipped with an electrically driven propeller. This device can serve for creating propulsion and/or lift of the aircraft. The aircraft can for instance be an aircraft with lifting wings or also a rotary wing aircraft, such as a helicopter or quadcopter (also including designs with more or less than four rotors).

**[0031]** As apparent from prior art mentioned at the beginning, aircrafts, such as planes for example, having electrically driven propellers currently are not only the subject of theoretical considerations, but are at the beginning of concrete developments for various use cases.

**[0032]** A need in the aviation field is the protection of man and technical equipment against the effects of lightning strikes in the air. The risk of a lightning strike to an aircraft, such as a plane for example, cannot be avoided. For this reason, corresponding technical measures should be taken in order to avert damage to man and technical equipment when a lightning strike occurs.

**[0033]** Nowadays, aircrafts such as planes either comprise a metallic outer shell or a correspondingly incorporated conductive tissue made of copper for example, to create a Faraday cage so that the regions inside the cage are protected against the effects of a lightning strike. Corresponding technologies are also used in the aircraft according to said one aspect of the present invention.

**[0034]** An electric machine driving a propeller may be arranged in a surrounding housing to achieve an aerodynamically advantageous design of the drive unit. By means of this housing a lightning protection of the electric machine itself is achieved with the known measures.

**[0035]** However, in aircraft drive devices equipped with propellers, the position of the propeller in the open air and its connection to the rotating shaft, e.g. to the rotor of the electric machine, via the driving shaft, can be a concern with respect to lightning protection. Now, when a lightning strikes the propeller or the front part of the rotor shaft, even the rotor of the electric machine is raised to the electric potential of the lightning via the rotor shaft. As the distance between the rotor and the stator (connected to ground potential) should, as a matter of principle, be kept as small as possible to achieve a good magnetic coupling, the high voltage difference caused by the lightning results in flashovers and various damages, e.g. the destruction of the insulation of the winding, damage to magnetic material, damage to surfaces as a result of melting etc.

**[0036]** The mechanical bearings of the rotor shaft may be a concern because of flashovers occur as a result of the high voltage difference and the small distances. In this case, this leads for instance to a decomposition of the lubricant, to damages to the bearing races, to undesired welding. Further damages to downstream power electronics and to the on-board electrical system of the plane may result from the high voltage difference.

**[0037]** While it would be theoretically possible with a corresponding effort to isolate the bearings to shield the rotor stator constellation from high voltage differences, providing a technically reasonable system to protect the rotor-stator-constellation has proven difficult.

**[0038]** Embodiments of the invention make it possible to realize a maintenance-free protection of the electric machine and the subsequent components against the effects of a lightning strike to the rotor shaft without modifying the machine itself.

**[0039]** In embodiments of the invention, the entry region of the rotor shaft (or any other protruding rotating shaft) to the surrounding housing, an element is arranged which diverts the overvoltage to the housing potential already at this stage and thus protects the subsequent machine and further components.

**[0040]** As a further measure and in combination with the above measure, a lightning protection coating that embodies the invention is provided which in the case of a lightning strike absorbs a part of the lightning energy by ablation and thus reduces the remaining energy to be diverted. Examples of corresponding coatings are described for instance in DE 10 2006 046 002 A1 or DE 10 2011 112 518 A1. For further details concerning the coating and the production thereof, reference is explicitly made to these documents, which are incorporated herein by reference.

**[0041]** This contactless overvoltage diversion function is performed without the use of any wearing elements such as sliding contacts, by using two mutually associated conductive elements (herein referred to as electrode elements on account of their function), one thereof being connected to the rotor shaft in a rotatable and conductive manner and the other one being stationarily and conductively connected to the housing and to the surrounding structure to which the lightning current shall be diverted. The elements are positioned relative to each other in such a way that they almost touch each other, except for a small air gap, and thus constitute a preferred location of flashover of the lightning from the rotor shaft to the structure.

**[0042]** A further aspect of embodiments of the invention is the design of regions between which the flashover now occurs in such a manner that a boost of the field is caused, which causes an ignition of the electric arc preferably at this stage. Even a nanostructured variant for increasing the local field strength as mentioned in DE 10 2006 046 002 A1 is possible.

**[0043]** An implemented isolation of the rotor shaft bearings from the housing/structure supports a flashover at the intended location.

**[0044]** The mutually associated electrode elements are designed in such a way that an electric arc once burning, which has a very low voltage drop as a result of the plasma channel, is kept burning preferably until the complete decay of the lightning current in order to avoid repeated overvoltage loads on the electric machine as a result of an interruption and new ignition of the electric arc. This can be achieved for instance by shielding that region against the relative wind, in order to prevent the cooling of the electric arc. A wind deflector element for protecting the electric arc is provided. This can be a separately provided element or a part of an already existing element, e.g. on the housing.

**[0045]** In the case of a lightning strike, a Faraday cage created by the housing is extended over the electrical machine and up to the location of the mutually associated elements.

**[0046]** According to one aspect, the invention provides a device that enables the diversion of an overvoltage between a rotating rotary shaft and a stationary part.

[0047] According to a further aspect, the invention relates to a device performing this diversion of an overvoltage in a contactless manner by flashover and an electric arc.

[0048] According to a further aspect, the inventions relates to a device that is designed with a field-boosting geometry so that the flashover preferably occurs at the intended location.

[0049] According to a further aspect, the invention relates to a device provided with a field-boosting coating so that the flashover occurs at the intended location.

[0050] According to a further aspect, the invention relates to a device capable of completely bearing the current flowing between the rotating and the stationary parts during a lightning strike, at least for the duration thereof, without the device being damaged or at least without losing its function.

[0051] According to a further aspect, the invention relates to a combination with a coating or any other measure capable of absorbing a part of the incoming lightning energy, in order to reduce the energy to be diverted from the device compared to the original lightning energy.

[0052] According to a further aspect, the invention relates to an isolation of the rotating bearing behind this device which isolates the rotating part from the stationary part and thus makes it unlikely that a flashover occurs in the region of the bearing.

[0053] According to a further aspect, the invention relates to an arrangement of the rotating and the stationary elements of the assembly in such a way that an electric arc is kept burning as long as possible in order to avoid repeated loads due to an overvoltage.

[0054] Although the invention and the advantages thereof have been described on the basis of embodiments of electric propeller drives, the invention is not limited to these embodiments, but can be applied to any drive unit for aircrafts in which rotating shafts protrude from a protective housing to the outside and in which an increase of the electric potential of the rotating shaft might cause problems or damages inside the housing, particularly by a lightning strike. For example, the rotating shaft drive machine may comprise a heat engine, such as a piston engine, gas turbine or a Wankel engine, wherein flashovers at the bearings may cause the above-described problems.

[0055] The housing can be a separate drive housing enclosing merely the rotary drive machine, but it can also be a general housing, e.g. a part of a structure of the aircraft, such as the fuselage or wing or tail unit where the rotary drive machine can be accommodated.

#### SUMMARY OF THE DRAWINGS

[0056] Embodiments of the invention will now be described in more detail below with reference to the attached drawing, wherein it is shown by:

[0057] FIG. 1 is a schematic representation of an aircraft drive device;

[0058] FIG. 2 is a schematic representation of an aircraft drive device according to one embodiment of the invention;

[0059] FIG. 3a an enlarged view of a detail of FIG. 2, showing an overcurrent arrester device of the aircraft drive device according to one embodiment;

[0060] FIG. 3b a sectional view of a further embodiment of the overvoltage arrester device;

[0061] FIG. 4 a schematic representation of a further embodiment of the aircraft drive device.

[0062] FIG. 5 illustrates an aircraft with an engine in a nacelle and a propeller.

#### DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

[0063] FIGS. 1, 2, 3a and 3b are schematic representations of an aircraft drive device 10, 10' for creating propulsion and/or lift of an aircraft 11. FIG. 1 shows an aircraft drive device 10', and FIG. 5 shows an aircraft 11 having a propeller 22 driving by an aircraft drive device housed in a nacelle 20. FIG. 2 and FIG. 4 show different embodiments of an aircraft drive device 10 in accordance with the invention.

[0064] The aircraft drive device 10, 10' serves for creating propulsion and/or lift of an aircraft and comprises a rotating shaft 12 supported by a first rotating shaft bearing 14 and a second rotating shaft bearing 16, a rotating shaft drive machine 18 for rotationally driving the rotating shaft 12, and a housing 20, such as a nacelle. The housing (nacelle) is mounted to an aircraft, such as to a lifting surface, e.g., a wing, or to a fuselage of the aircraft.

[0065] On the rotating shaft 12, a propeller 22 is provided in particular, while a propeller in this case may also be understood to be a main rotor of a rotorcraft.

[0066] The housing 20 may also be part of an aircraft structure (such as the fuselage or wing) and may serve for realizing an aerodynamically advantageous design of the drive unit of the aircraft. The housing 20 is designed for providing a lightning protection for the rotating shaft drive machine 18. For this purpose, the housing especially creates a Faraday cage 24. To this end the housing 20 itself can be made of a conductive material, such as metal for example. In a particularly preferred form of construction, a shell of the housing 20 is formed of a composite material, such as CFRP (carbon-fiber-reinforced plastic), having embedded therein a (metallic) conductive layer or a conductive grid or a (metallic) conductive mesh or a tissue of a conductive material. Preferably, the housing 10 is provided on its surface with a coating, such as described and shown in DE 10 2006 046 002 A1 or DE 10 2011 112 518 A1.

[0067] In particular, the housing 20 with its Faraday cage 24 is at an electric housing potential 26; and correspondingly conductive regions or layers of the housing 20 are preferably electrically connected to the electrical ground of the aircraft.

[0068] The rotating shaft 12 can also be made of a metallically conductive material or of composite materials, in particular CFRP. Also the rotating shaft 12 is preferably provided with at least one conductive layer or an axially extending conductive web being at an electrical rotating shaft potential 28.

[0069] The rotating shaft drive machine 18 particularly comprises an electric machine 30 and more particularly an electric motor 32 having a stator 34 (shown in a cut-open view in the Figures) whose electric potential is also connected to the ground and thus is at the housing potential 26, and a rotor 36, wherein a rotor shaft of the rotor 36 is connected to or constitutes the rotating shaft 12.

[0070] The rotating shaft bearings 14, 16 serve for supporting the rotating shaft 12 and respectively comprise a stationary bearing element 38 and rotatable bearing element 40. The stationary bearing element 38 is connected in a stationary manner and can be at the housing potential 28 and/or grounded. The rotatable bearing element 40 is connected to the rotating shaft 12 and can be at the rotating shaft

potential 28. The bearing elements 38, 40 can for instance be bearing shells with bearing rollers running between them.

[0071] Since the propeller 22 rotates in the outer space outside the housing 20, the rotating shaft 12 passes from the interior 44 of the housing 20 through a housing opening 42 to the exterior of the housing 20 and thus protrudes through this housing opening 42 to the outside. A propeller 22 is attached to the protruding end of the rotating shaft 12. For example, the rotating shaft 12 terminates towards the outside with a rotor nose (not further illustrated).

[0072] FIG. 1 shows an aircraft drive device 10' without the inventive measures. If a lightning 46 strikes the propeller 22 or the protruding end of the rotating shaft 12, even the rotor 36 of the electric machine 30 will be raised to the electric potential of the lightning 46 via the rotating shaft 12—rotor shaft. A dashed line in FIG. 1 and FIG. 2 shows the respective path of the current 48 in the case of a lightning strike. As the distance between the rotor 36 and the grounded stator 34 should be kept as small as possible in order to achieve a good magnetic coupling, flashovers may occur in this case as a result of the high voltage difference caused by the lightning 46 and may cause various damages, such as the destruction of the insulation of the winding, damages to magnetic material, damages to surfaces caused by melting etc. Additional flashovers 50 may occur between the bearing elements 38, 40 of the rotating shaft bearings 14, 16, particularly the first rotating shaft bearing 14 between the housing opening 42 and the electric machine 30. The flashovers 50 between the bearing elements 38, 40 may lead to a decomposition of a lubricant, to damages to the bearing races or to undesired material welding etc.

[0073] To avoid these problems, in the inventive aircraft drive device 10 according to FIG. 2 and FIG. 4, an overvoltage arrester device 52 is arranged in the region of the housing opening 42. The overvoltage arrester device 52 is designed for diverting an overvoltage present at the rotating shaft 12 from the rotating shaft potential 28 to the housing potential 26 and/or to ground.

[0074] Possible embodiments of the overvoltage arrester device 52 are shown in FIG. 3a and FIG. 3b.

[0075] The overvoltage arrester device 52 comprises a stationary element and a rotating element 12 rotating together with the rotating shaft 12, and the overvoltage is diverted between these two elements. This preferably takes place in a contactless manner by an electric arc. Because of their function, the elements of the overvoltage arrester device 52 are hereinafter referred to as electrode elements, wherein the overvoltage occurs between these electrode elements.

[0076] Accordingly, in an embodiment, the overvoltage arrester device 52 comprises a stationary electrode element 54, which is electrically connected to ground and/or to the housing potential 26. The overvoltage arrester device 52 further comprises a rotating electrode element 56 that is connected to the rotating shaft 12 and is electrically at the rotating shaft potential 28. In particular, the electrode elements 54, 56 comprise ring electrodes with facing electrode surfaces 60 that are spaced from each other by a gap 62, which is as small as possible. Preferably, the gap distance 64 between the electrode elements 54, 56 is so small that the smallest distance in the region of the electrode elements 54, 56 is created between the housing potential 26 and the rotating shaft potential 28.

[0077] In the embodiment shown in FIG. 3a, one of the electrode elements 56 is received between two regions of the other electrode element 54. For example, one of the electrode elements 54 comprises two ring electrodes 58 between which the ring electrode 58 of the other electrode element 56 is received.

[0078] In a concrete exemplary construction, an outer ring 66 and an inner ring 68 made of or provided with an electrically conductive material are provided on the housing opening 42, and a ring 70 attached to and radially spaced from the rotating shaft 12 engages between said outer ring and an inner ring.

[0079] As shown in FIG. 3b, the electrode elements 54, 56 may be provided with field-boosting structures 72 or field-boosting geometries. In particular, spikes of a conductive material may be provided (which can also be surrounded by a dielectric).

[0080] Even more particularly, in one of the configurations shown in DE 10 2006 046 002 A1 or DE 10 2011 112 518 A1, the field-boosting structure 72 is provided in a coating 78 of the electrode surface 60. The corresponding field-boosting structures 72 may be provided on the electrode surfaces 60 of the ring electrodes 58.

[0081] In the construction shown in FIG. 3b, a radially inner surface of a stationary ring 66, 68 surrounding the rotating shaft 12 with the small gap distance 64 of the gap 62 is provided with the field-boosting structure 72, and also the peripheral surface 80 of the rotating shaft 12 is provided with a field-boosting structure 72 in this region.

[0082] By corresponding measures, see FIG. 2, the overvoltage at the rotating shaft potential 28 caused by the lightning 46 at the time of the lightning strike is diverted to the housing 20 via the overvoltage arrester device 52 in the region of the entry of the rotating shaft 12 so that the inner structures of the aircraft drive device 12 are protected against overvoltage.

[0083] As a supporting measure, also the rotating shaft bearings 14, 16 are provided with an electrical insulation 82.

[0084] The transition of the overvoltage takes place by an electric arc 84 that should be maintained until the lightning energy has been diverted as far as possible.

[0085] For this reason, the overvoltage arrester device 52 is either protected from relative wind or wind produced by the propeller 22 by the stationary outer ring 66 as a wind deflector element 86 or by providing a separate wind deflector element 86 for deflecting wind 88 as in the further embodiment shown in FIG. 4.

[0086] The aircraft drive device 10 can be used for driving or propelling various aircrafts, such as airplanes, helicopters, rotorcrafts. For further details concerning the aircraft, reference is made to the embodiments described in DE 10 2005 006 511 A1, DE 10 2013 109 392 A1, DE 10 2019 021 024 B1, DE 10 2013 101 602 A1 and DE 10 2006 056 356 A1 showing further features for a possible design of the propeller/rotor and/or the aircraft drive device 10.

[0087] In an embodiment, the aircraft drive device 10 for producing propulsion and/or lift of an aircraft comprises a rotating shaft 12, a rotating shaft bearing 14, 16, a rotating shaft drive machine 18 for rotationally driving the driving shaft 12, and a housing 20, wherein the rotating shaft bearing 14, 16 and the rotating shaft drive machine 18 are arranged in the interior of the housing 44 and the rotating shaft 12 protrudes to the outside of the housing 20 through a housing opening 42, wherein in the region of said housing opening

**42** an overvoltage arrester device **52** is arranged which is designed for diverting an overvoltage present at the rotating shaft **12**.

**[0088]** The aircraft drive device **10** may have one or more of the following features:

**[0089]** (a) the rotating shaft drive machine **18** is an electric machine **30**, in particular an electric motor **32** having a rotor **36** and a stator **34**;

**[0090]** (b) an electrically driven propeller **22**;

**[0091]** (c) a propeller **22** is arranged on the part of the rotating shaft **12** protruding from the housing **20**;

**[0092]** (d) a first rotating shaft bearing **14** and a second rotating shaft bearing **16**;

**[0093]** (e) the housing **20** is designed for creating a lightning protection for the rotating shaft drive machine **18** itself;

**[0094]** (f) the housing **20** creates a Faraday cage **24** and/or

**[0095]** (g) at least a region of the rotating shaft **12** is at an electric rotating shaft potential **26** and at least a region of the housing **20** is at a housing potential **26**, wherein the overvoltage arrester device **52** is designed for diverting the overvoltage from the rotating shaft potential **28** to the housing potential **26**.

**[0096]** In the aircraft drive device **10** the overvoltage arrester device **52** may comprise a stationary electrode element **54** designed for diverting an overvoltage and a rotatable electrode element **56** being at rotating shaft potential **28**, wherein the electrode elements **54**, **56** are spaced by a gap **62**, for a contact-free voltage transfer of overvoltage.

**[0097]** The overvoltage arrester device **52** in the aircraft drive device **10** may have one or more of the following features:

**[0098]** (a) at least one of the electrode elements **54**, **56** is ring-shaped;

**[0099]** (b) at least one of the electrode elements **54**, **56** comprises a first ring **66** and a second ring **68** between which the other electrode element **54**, **56** is received;

**[0100]** (c) the electrode elements **54**, **56** may have substantially parallel opposing electrode surfaces **60** between which said gap **62** is formed;

**[0101]** (d) at least one of the electrode elements **54**, **56** comprises an electric arc ignition element for igniting a plasma channel in the gap for the purpose of transferring the overvoltage;

**[0102]** (e) at least one of the electrode elements **54**, **56** is provided with a tip **74** of a conductive material;

**[0103]** (f) at least one of the electrode elements **54**, **56** is provided with a coating in which spikes **74** of conductive particles and/or polarizable particles are provided;

**[0104]** (g) the gap **62** represents the smallest distance between the rotating shaft potential **28** and the housing potential **26**; and

**[0105]** (h) the gap **62** has a gap distance **64** in the range of 0.1  $\mu\text{m}$  to 10 mm, preferably in the range of 0.01 mm to 5 mm.

**[0106]** In the aircraft drive device **10**, the rotating shaft bearing **14**, **16** may comprise a stationary bearing element **38** and a rotatable bearing element **40** and an electric insulation **82** for electrically insulating said stationary bearing element **38** from said rotatable bearing element **40**.

**[0107]** In the aircraft drive device **10**, at least a region of the rotating shaft **12** and/or of the housing **20** is provided with a lightning protection coating **78**.

**[0108]** In the aircraft drive device **10**, the lightning protection coating **78** is chosen among one or more of a group of coatings **78** including a coating **78** with an electrically conductive layer, a coating **78** with an electrically conducting grid, a coating **78** with electrically polarizable particles, a coating **78** with electrically conductive particles provided with spikes **74**, a coating **78** with electrically conductive particles in a dielectric matrix, a coating **78** with electrically conductive particles provided with spikes **74** in a dielectric matrix, and a coating **78** with electrical ignition elements for igniting an electric arc **84**.

**[0109]** In the aircraft drive device **10**, the overvoltage arrester device **52** may comprise a wind deflector device **86** for the protection of the electric arc **84**.

**[0110]** In the aircraft drive device **10**, the overvoltage arrester device **52** may be configured in one or more of the following manners:

**[0111]** (a) enable the diversion of an overvoltage between the rotating rotary shaft **12** and stationary part;

**[0112]** (b) designed in such a way that the diversion of the overvoltage takes place in a contactless manner by flashover **50** and an electric arc **84**;

**[0113]** (c) have a field-boosting geometry so that the flashover occurs at the intended location; and

**[0114]** (d) provided with a field-boosting coating **78** so that the flashover preferably occurs at the intended location.

**[0115]** An aircraft may include the aircraft drive device **10**.

**[0116]** While at least one exemplary embodiment of the present invention(s) is disclosed herein, it should be understood that modifications, substitutions and alternatives may be apparent to one of ordinary skill in the art and can be made without departing from the scope of this disclosure. This disclosure is intended to cover any adaptations or variations of the exemplary embodiment(s). In addition, in this disclosure, the terms "comprise" or "comprising" do not exclude other elements or steps, the terms "a" or "one" do not exclude a plural number, and the term "or" means either or both. Furthermore, characteristics or steps which have been described may also be used in combination with other characteristics or steps and in any order unless the disclosure or context suggests otherwise. This disclosure hereby incorporates by reference the complete disclosure of any patent or application from which it claims benefit or priority.

#### LIST OF REFERENCE NUMBERS

<b>[0117]</b>	<b>10</b> aircraft drive device
<b>[0118]</b>	<b>10'</b> aircraft drive device (not in accordance with the present invention)
<b>[0119]</b>	<b>11</b> aircraft
<b>[0120]</b>	<b>12</b> rotating shaft
<b>[0121]</b>	<b>14</b> first rotating shaft bearing
<b>[0122]</b>	<b>16</b> second rotating shaft bearing
<b>[0123]</b>	<b>18</b> rotating shaft drive machine
<b>[0124]</b>	<b>20</b> housing
<b>[0125]</b>	<b>22</b> propeller
<b>[0126]</b>	<b>24</b> Faraday cage
<b>[0127]</b>	<b>26</b> housing potential
<b>[0128]</b>	<b>28</b> rotating shaft potential
<b>[0129]</b>	<b>30</b> electric machine
<b>[0130]</b>	<b>32</b> electric motor
<b>[0131]</b>	<b>34</b> stator (shown cut-open)
<b>[0132]</b>	<b>36</b> rotor
<b>[0133]</b>	<b>38</b> stationary bearing element
<b>[0134]</b>	<b>40</b> rotatable bearing element



[0135]	42	housing opening
[0136]	44	interior of the housing
[0137]	46	lightening
[0138]	48	current path
[0139]	50	flashover
[0140]	52	overvoltage arrester device
[0141]	54	stationary electrode element
[0142]	56	rotating electrode element
[0143]	58	ring electrodes
[0144]	60	electrode surface
[0145]	62	gap
[0146]	64	gap distance
[0147]	66	stationary outer ring
[0148]	68	stationary inner ring
[0149]	70	rotatable ring
[0150]	72	field-boosting structure
[0151]	74	spike
[0152]	78	coating
[0153]	80	peripheral surface
[0154]	82	electric insulation
[0155]	84	electric arc
[0156]	86	wind deflector element
[0157]	88	wind

The invention is:

1. An aircraft drive device for producing propulsion and/or lift of an aircraft comprising:

- a rotating shaft,
- a rotating shaft bearing,
- a rotating shaft drive machine for rotationally driving the driving the rotating shaft, and
- a housing, wherein the rotating shaft bearing and the rotating shaft drive machine are arranged in an interior of the housing, and the rotating shaft protrudes outside of the housing through a housing opening, and
- an overvoltage arrester device is arranged in a region of the housing opening and is configured to divert an overvoltage present at the rotating shaft.

2. The aircraft drive device according to claim 1, wherein the rotating shaft drive machine is an electric motor having a rotor and a stator.

3. The aircraft device according to claim 1 wherein the aircraft drive device further comprises a propeller arranged on a portion of the rotating shaft protruding outside of the housing.

4. The aircraft device according to claim 1 wherein the rotating shaft bearing includes a first rotating shaft bearing and a second rotating shaft bearing.

5. The aircraft device according to claim 1 wherein the housing is configured as a Faraday cage to provide lightening protection for the rotating shaft drive machine.

6. The aircraft device according to claim 1 wherein at least a region of the rotating shaft is at an electric rotating shaft voltage potential and at least a region of the housing is at a housing voltage potential, wherein the overvoltage arrester device is configured to divert is configured to divert the overvoltage from the rotating shaft potential to the housing potential.

7. The aircraft drive device according to claim 1, wherein the overvoltage arrester device comprises a stationary electrode element configured to divert the overvoltage and a rotatable electrode element configured to be at a rotating shaft voltage potential, wherein the stationary and rotatable

electrode elements are spaced apart by a gap which provides a contact-free voltage transfer of overvoltage through the overvoltage arrester.

8. The aircraft drive device according to claim 7, wherein the stationary and rotatable electrode elements are at least one of:

- the stationary and rotatable electrode elements are each ring-shaped elements;

- one of the stationary and rotatable electrode elements includes a first ring and a second ring, and the other of the stationary and rotatable electrode elements is between the first ring and the second ring;

- the stationary and rotatable electrode elements have opposing electrode surfaces separated by the gap;

- at least one of the stationary and rotatable electrode elements includes an electric arc ignition element configured to ignite a plasma channel to divert the overvoltage;

- at least one of the stationary and rotatable electrode elements includes a tip of conductive material,

- at least one of the stationary and rotatable electrode elements provided with a coating having spikes of conductive particles and/or polarizable particles;

- wherein the gap represents smallest distance between the rotating shaft potential and the housing potential; and wherein the gap that the gap is a distance in a range of 0.1  $\mu\text{m}$  to 10 mm.

9. The aircraft drive device according to claim 1. Wherein the rotating shaft bearing comprises a stationary bearing element and a rotatable bearing element, and an electric insulation configured to electrically insulate the stationary bearing element from the rotatable bearing element.

10. The aircraft drive device according to claim 1 wherein at least a region of the rotating shaft and/or of the housing is provided with a lightening protection coating, wherein the lightening protection coating is at least one of:

- a coating with an electrically conductive layer,

- a coating with an electrically conducting grid,

- a coating with electrically polarizable particles,

- a coating with electrically conductive particles provided with spikes,

- a coating with electrically conductive particles in a dielectric matrix,

- a coating with electrically conductive particles provided with spikes in a dielectric matrix, and

- a coating with electrical ignition elements for igniting an electric arc.

11. The aircraft drive device according claim 1 wherein the overvoltage arrester device comprises a wind deflector device configured to protection an electric arc.

12. The aircraft drive device according to claim 1 wherein the overvoltage arrester device is configured as at least one of:

- enable the diversion of an overvoltage between the rotating rotary shaft and the stationary part;

- to divert the overvoltage in a contactless manner by flashover and an electric arc);

- to have a field-boosting geometry; and

- to have a field-boosting coating.

13. An aircraft comprising the aircraft drive device according claim 1.

14. An aircraft drive device and nacelle assembly mounted to an aircraft, the assembly comprising:

a nacelle configured to be mounted to an aircraft wing or fuselage, wherein the nacelle has a forward facing opening;

an aircraft drive device housed in the nacelle;

a shaft rotatably driven by the aircraft drive device, wherein the shaft extends forward of the aircraft drive device through the opening in the nacelle and outward of the nacelle;

an overvoltage arrester device in the nacelle and including:

a conductive rotating electrode element attached to and rotating with the shaft,

a conductive stationary electrode element conductively coupled to the aircraft, wherein the conductive rotating electrode is attached to the shaft forward of the aircraft engine, and

a gap separating the conductive rotating electrode and the conductive stationary electrode element, wherein the gap is in a range of 0.1  $\mu\text{m}$  to 10 mm.

**15.** The aircraft drive device and nacelle assembly of claim **14** wherein the overvoltage arrester device is proximate the opening in the nacelle.

**16.** The aircraft drive device and nacelle assembly of claim **14** wherein the conductive rotating electrode is a first ring electrode centered on the shaft and the conductive stationary electrode is a second ring electrode having a conductive surface facing and parallel to a conductive surface of the first ring electrode, wherein the gap is between the conductive surfaces.

**17.** The aircraft drive device and nacelle assembly of claim **16** wherein each of the coatings includes at least one of:

an electrically conductive layer,  
 an electrically conducting grid,  
 electrically polarizable particles,  
 electrically conductive particles provided with spikes,  
 electrically conductive particles in a dielectric matrix,

electrically conductive particles provided with spikes in a dielectric matrix, and

electrical ignition elements configured to ignite an electric arc in the gap.

**18.** The aircraft drive device according claim **1** wherein at least one of the conductive rotating electrode element and the conductive stationary electrode element includes an electric arc ignition element configured to ignite a plasma channel in the gap.

**19.** A method to divert electricity from a lighting strike away from an aircraft drive device, the method comprising: driving a shaft by an aircraft drive device, wherein the aircraft drive device is housed in a nacelle of an aircraft and the shaft extends forward of an opening in the nacelle;

conducting electricity from a lighting strike on the shaft or on a propeller mounted to the shaft along the shaft to an overvoltage arrester device mounted to the shaft forward of the aircraft drive device, wherein the overvoltage arrester device includes a conductive rotating electrode mounted to the shaft and a conductive stationary electrode mounted to and conductively coupled to the aircraft;

the conducted electricity flashes over a gap between the conductive rotating electrode and the conductive stationary electrode to allow the conducted electricity to flow from the conductive rotating electrode to the conductive stationary electrode, and

diverting the conducted electricity away from the aircraft drive device by the flashover of the conducted electricity to the conductive stationary electrode.

**20.** The method of claim **19** further comprising using the gap to electrically isolate the conductive rotating electrode from the conductive stationary electrode, wherein the lightning strike and the flashover overcomes the isolation.

\* \* \* \* \*