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Addtively manufactured bi-metal integral shaft and motor rotor heat exchanger and tie rod for ram air fan

Abstract

A journal bearing shaft is provided and includes a single monolithic body. The single monolithic body includes a tie rod, an end cap integrally connected to and extending radially outwardly from an end of the tie rod and defining openings, a journal bearing interface portion integrally connected to and extending aft from a distal edge of the end cap and a bi-metal heat exchanger integrally connected to and extending aft from an aft edge of the journal bearing interface portion and including an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the exterior body and the tie rod.

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Background/Summary

BACKGROUND

(1) The present disclosure relates to ram air fan construction and, more particularly, to an additively manufactured bi-metal integral shaft and motor rotor heat exchanger and tie rod for a ram air fan.

(2) Fans are often used to move air. Fans may, for example, move air through heat exchangers of air conditioning packs on aircraft. The air moved by the fans cools the heat exchangers. Such fans within aircraft are often ram air fans. When the aircraft is on the ground, motors are typically used to rotate the rotors of the ram air fans. Absent intervention, thermal energy from the motor can build up within components of fans used in this manner. Ram air fans typically include heat exchangers to remove heat from the components susceptible to thermal buildup.

(3) Existing heat exchangers utilized for this purpose typically include heat dissipation fins constructed of folded sheet metal, with the fins being brazed, or otherwise affixed as a heat exchanger insert into a housing structure, such as a journal bearing shaft. This combined structure

is placed in thermal communication with the motor, and cooling air is passed over the fins thereby cooling the motor. Such heat exchange structures are complex, expensive, time consuming to construct and are difficult to repair.

SUMMARY

(4) According to an aspect of the disclosure, a journal bearing shaft is provided and includes a single monolithic body. The single monolithic body includes a tie rod, an end cap integrally connected to and extending radially outwardly from an end of the tie rod and defining openings, a journal bearing interface portion integrally connected to and extending aft from a distal edge of the end cap and a bi-metal heat exchanger integrally connected to and extending aft from an aft edge of the journal bearing interface portion and including an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the exterior body and the tie rod.

(5) In accordance with additional or alternative embodiments, a length of the tie rod exceeds a total length of the journal bearing interface portion and the bi-metal heat exchanger.

(6) In accordance with additional or alternative embodiments, the end cap includes an inboard end cap portion, which extends radially outwardly from the end of the tie rod, and an outboard end cap portion, which extends radially outwardly and aft from a distal edge of the inboard end cap portion.

(7) In accordance with additional or alternative embodiments, the journal bearing interface portion and the bi-metal heat exchanger are coaxial with the tie rod.

(8) In accordance with additional or alternative embodiments, an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.

(9) In accordance with additional or alternative embodiments, at least one or more of the tie rod, the end cap and the journal bearing interface portion is formed of the first material.

(10) In accordance with additional or alternative embodiments, the first material is one or more of stainless steel and Inconel™ and the second material is one or more of copper, nickel or nickel alloys, corrosion resistant steel, aluminum alloys and titanium.

(11) According to an aspect of the disclosure, a ram air fan assembly is provided and includes a fan rotor to move air from a fan inlet to a fan outlet and a journal bearing shaft disposed as a single monolithic body within the fan rotor and defining a flow path for cooling air. The single monolithic body includes a tie rod, an end cap integrally connected to and extending radially outwardly from an end of the tie rod and defining openings, a journal bearing interface portion integrally connected to and extending aft from a distal edge of the end cap and a bi-metal heat exchanger integrally connected to and extending aft from an aft edge of the journal bearing interface portion and including an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the exterior body and the tie rod.

(12) In accordance with additional or alternative embodiments, a length of the tie rod exceeds a total length of the journal bearing interface portion and the bi-metal heat exchanger.

(13) In accordance with additional or alternative embodiments, the end cap includes an inboard end cap portion, which extends radially outwardly from the end of the tie rod, and an outboard end cap portion, which extends radially outwardly and aft from a distal edge of the inboard end cap portion.

(14) In accordance with additional or alternative embodiments, the journal bearing interface portion and the bi-metal heat exchanger are coaxial with the tie rod.

(15) In accordance with additional or alternative embodiments, an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.

(16) In accordance with additional or alternative embodiments, at least one or more of the tie rod, the end cap and the journal bearing interface portion is formed of the first material.

(17) In accordance with additional or alternative embodiments, the first material is one or more of stainless steel and Inconel™ and the second material is one or more of copper, nickel or nickel alloys, corrosion resistant steel, aluminum alloys and titanium.

(18) According to an aspect of the disclosure, a method of additively manufacturing a journal bearing shaft as a single monolithic body with a bi-metal construction is provided. The method includes building up a first tie rod portion, simultaneously building up a second tie rod portion from the first tie rod portion and a bi-metal heat exchanger about the second tie rod portion to include an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the second tie rod portion and the exterior body, simultaneously building up a third tie rod portion from the second tie rod portion and a journal bearing interface portion from the bi-metal heat exchange portion and about the third tie rod portion and simultaneously building up an end of the tie rod from the third tie rod portion and an end cap from the journal bearing interface portion to connect with the end of the tie rod.
(19) In accordance with additional or alternative embodiments, the building up of the end cap includes building up an inboard end cap portion to extend radially outwardly from the end of the tie rod and building up an outboard end cap portion from the journal bearing interface portion to extend radially outwardly and aft from a distal edge of the inboard end cap portion.
(20) In accordance with additional or alternative embodiments, the building up of the bi-metal heat exchanger and the second tie rod portion is executed such that the bi-metal heat exchanger and the second tie rod portion are coaxial and the building up of the journal bearing interface portion and the third tie rod portion are executed such that the journal bearing interface portion and the third tie rod portion are coaxial.
(21) In accordance with additional or alternative embodiments, the building up of the bi-metal heat exchanger and the journal bearing interface portion are executed such that an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.
(22) In accordance with additional or alternative embodiments, the building up of the bi-metal heat exchanger includes simultaneously feeding the first material and the second material into an additive manufacturing tool.
(23) In accordance with additional or alternative embodiments, the building up of the bi-metal heat exchanger includes simultaneously feeding the first material into a first additive manufacturing tool and feeding the second material into a second additive manufacturing tool.
(24) Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed technical concept. For a better understanding of the disclosure with the advantages and the features, refer to the description and to the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) For a more complete understanding of this disclosure, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts:
(2) FIG. **1** is a side view of a ram air fan assembly in accordance with embodiments;
(3) FIG. **2** is a perspective view of a journal bearing shaft provided as a single monolithic body for the ram air fan assembly of FIG. **1** in accordance with embodiments;
(4) FIG. **3** is a side view of the journal bearing shaft of FIG. **2** installed in a ram air fan assembly in accordance with embodiments;
(5) FIG. **4** is a schematic illustration of an angling of heat exchange fins of the journal bearing shaft of FIGS. **2** and **3** in accordance with embodiments;
(6) FIG. **5** is an axial view of a heat exchange element with a bi-metal construction in accordance

with embodiments;
(7) FIG. **6** is a flow diagram illustrating a method of additively manufacturing a journal bearing shaft as a single monolithic body in accordance with embodiments; and
(8) FIG. **7** is a flow diagram illustrating a method of additively manufacturing a journal bearing shaft as a single monolithic body with a bi-metal construction in accordance with embodiments.

DETAILED DESCRIPTION

(9) In conventional ram air fans, a stainless steel shaft supports a motor rotor and provides for a journal bearing interface and motor rotor cooling air flows proceed through a shaft inner diameter. Current heat exchangers are typically fabricated from sheet metal and are formed with fins that are brazed onto the shaft. A spring at the inner diameter supports and is brazed to the fins. This arrangement can lead to expense and complexity and the brazing often requires rework, repair and scrapping of faulty parts.

(10) Thus, as will be described below, a ram air fan is provided with an additively manufactured shaft with integral an integral heat exchanger. An end cap and a tie rod, which are typically separate, can also be integrated into the shaft. This eliminates a need for a nut and washer combination on the end of the shaft. The shaft assembly can be formed of various materials including, but not limited to, stainless steel, Inconel™ or other similar materials or combinations thereof. For a bi-metallic configuration, the heat exchange fin material can include, but is not limited to, one or more of copper, nickel or nickel alloys (such as 200AM, In625 or other similar materials or combinations thereof), corrosion resistant steel (17-4 or similar), aluminum alloys (A20× or similar), titanium or combinations thereof. The tie rod can be connected to an inner diameter of a cylinder of the heat exchanger or held to close clearance. A connection to the inner diameter of the heat exchanger eliminates the need for a central support and provides for a clearance benefit if more stretch and/or preload is desired.

(11) With reference to FIG. **1**, a ram air fan assembly **10** is provided and it is to be appreciated that various structures and assemblies may be altered from the example embodiment while still falling within the scope of the systems and methods described herein. The ram air fan assembly **10** includes a fan housing **12**, a bearing housing **14**, an inlet housing **16**, an outer housing **18** and an inner housing **20**. The fan housing **12** includes fan struts **22**, a motor **24** including a motor rotor **26** and a motor stator **28**, a thrust shaft **30**, a thrust plate **32** and thrust bearings **34**. The bearing housing **14** includes a journal bearing shaft **36** and a shaft cap **38**. The fan housing **12** and the bearing housing **14** together include a tie rod **40** and journal bearings **42**. The inlet housing **16** includes a fan rotor **44**, a shroud **46** and a hub **48** in addition to a portion of the tie rod **40**. The outer housing **18** includes a terminal box **50** and a plenum **52**. Within the outer housing **18** are a diffuser **54**, a motor bearing cooling tube **56** and a wire transfer tube **58**. A fan inlet is a source of air to be moved by the ram air fan assembly **10** in the absence of sufficient ram air pressure. A bypass inlet is a source of air that moves through ram air fan assembly **10** when sufficient ram air pressure is available. The ram air fan assembly **10** further includes drain holes **60** in the fan housing **12**. Axis Z extends along a central axis of ram air fan assembly **10**.

(12) As illustrated in FIG. **1**, the inlet housing **16** and the outer housing **18** are attached to the fan housing **12** at the fan struts **22**. The bearing housing **14** is attached to the fan housing **12** and the inner housing **20** connects the motor bearing cooling tube **56** and the wire transfer tube **58** to the bearing housing **14**. The motor bearing cooling tube **56** connects the inner housing **20** to a source of cooling air at the outer housing **18**. The wire transfer tube **58** connects the inner housing **20** to the outer housing **18** at the terminal box **50**. The motor stator **28** and the thrust plate **32** attach to the fan housing **12**. The motor rotor **26** is included within the motor stator **28** and connects the journal bearing shaft **36** to the thrust shaft **30**. The journal bearing shaft **36**, the motor rotor **26** and the thrust shaft **30** define an axis of rotation for the ram air fan assembly **10**. The fan rotor **44** is attached to the thrust shaft **30** with the tie rod **40** extending along the axis of rotation from the shaft cap **38** at the end of the journal bearing shaft **36** through the motor rotor **26**, the thrust shaft **30** and

the fan rotor **44** to the hub **48** and the shroud **46**. Nuts (not shown) secure the shaft cap **38** to the journal bearing shaft **36** on one end of the tie rod **40** and the hub **48** and the shroud **46** to the fan rotor **44** at an opposite end of the tie rod **40**. The thrust plate **32** and the fan housing **12** include a flange-like portion of the thrust shaft **30**, with the thrust bearings **34** positioned between the flange-like portion of the thrust shaft **30** and the thrust plate **32** and between the flange-like portion of the thrust shaft **30** and the fan housing **12**. The journal bearings **42** are positioned between the journal bearing shaft **36** and the bearing housing **14** and between the thrust shaft **30** and the fan housing **12**. The hub **48**, the shroud **46**, the fan rotor **44** and a portion of the fan housing **12** are included within the inlet housing **16**. The diffuser **54** is attached to an inner surface of the outer housing **18**. The plenum **52** can be provided as a portion of the outer housing **18** that connects the ram air fan assembly **10** to the bypass inlet. The inlet housing **16** is connected to the fan inlet and the outer housing **18** is connected to the fan outlet.

(13) In operation, the ram air fan assembly **10** is installed into an environmental control system (ECS) aboard an aircraft and is connected to the fan inlet, the bypass inlet and the fan outlet. When the aircraft does not move fast enough to generate sufficient ram air pressure to meet the cooling needs of the ECS, power is supplied to motor stator **28** by wires running from the terminal box **50**, through the wire transfer tube **58**, the inner housing **20** and the bearing housing **14**. Energizing the motor stator **28** causes the rotor **24** to rotate about axis Z thereby rotating the journal bearing shaft **36** and the thrust shaft **30**. The fan rotor **44**, the hub **48** and the shroud **46** also rotate by way of their respective connections to the thrust shaft **30**. The journal bearings **42** and the thrust bearings **34** provide low friction support for the rotating components. As the fan rotor **44** rotates, it moves air from the fan inlet, through the inlet housing **20**, past the fan struts **22** and into the space between the fan housing **12** and the outer housing **18**, increasing the air pressure in the outer housing **18**. As the air moves through the outer housing **18**, it flows past the diffuser **54** and the inner housing **20**, where the air pressure is reduced due to the shape of the diffuser **54** and the shape of the inner housing **20**. Once past the inner housing **20**, the air moves out of the outer housing **18** at the fan outlet.

(14) Components within the bearing housing **14** and the fan housing **12**, especially the thrust bearings **34**, the journal bearings **42** and the motor **24**, generate significant heat and are cooled to prevent sub-optimal operation. Cooling air **70** is provided by the motor bearing cooling tube **56** which directs the flow of cooling air **70** to the inner housing **20**. The inner housing **20** directs the flow of cooling air **70** to the bearing housing **14**, where the cooling air **70** flows past components in the bearing housing **14** and the fan housing **12**, the thrust plate **32**, the tie rod **40** and components of the motor **24**. In some examples, one of the routes available for the cooling air is through the journal bearing shaft **36**, allowing heat exchange fins included within the journal bearing shaft **36** to enhance heat transfer and improve the cooling effect. The cooling air **70** then exits the fan housing **12** through cooling holes in the fan rotor **44**. Condensation can form and settle in the fan housing **12** when the cooling air **70** mixes with the heat from the thrust bearings **34**, the journal bearings **42** and the motor **24** in the fan housing **12**. This condensation can cause problems with the operation of the journal bearings **42** and the motor **24**. The drain holes **60** are provided in the fan housing **12** to drain the condensation out of the fan housing **12** and into the air flowing through the ram air fan assembly **10** and out of the fan outlet.

(15) The cooling air **70** of FIG. **1** is illustrated as generally traveling along a single flow path through the journal bearing shaft **36**. It is appreciated, however, that the cooling air **70** drawn through the cooling tube **56** may be passed along additional flow paths through the inner housing **20** to cool additional components.

(16) Existing ram air fan assemblies typically utilize cast and milled components, and the design features of the components are limited due to the limitations of those manufacturing processes. However, utilization of modern additive manufacturing techniques, and particularly additively manufactured metal components, allows for the construction of integral parts having internal

features and shapes and also allows for tighter tolerances and thinner structural components while still allowing the components to be formed as a single integral structure without using joints, fasteners or material adhesion (e.g., brazing). The single integral piece designs facilitated by additive manufacturing reduce overall complexity and improve corresponding assembly processes.

(17) Thus, with continued reference to FIG. **1** and with additional reference to FIG. **2**, an additively manufactured journal bearing shaft **200** is provided and includes single monolithic body **201** that in turn includes an end cap **204**, a main body **206**, a journal bearing interface portion **208**, a tie rod **210** and a heat exchange element **220**, which includes heat exchange fins **222** and an exterior body **224**. The end cap **204**, the main body **206**, the journal bearing interface portion **208**, the tie rod **210** and the heat exchange element **220** including the heat exchange fins **222** and the exterior body **224** are all integral with one another, radially balanced about the axis Z and possessed of a suitable overall strength. A set of openings **230** at the end cap **204** provide for cooling air passages that allow the cooling air flow **70** (see FIG. **1**) to enter and pass through the interior of the journal bearing shaft **200** and the heat exchange element **220**.

(18) The single monolithic body **201** of the journal bearing shaft **200** can be disposed as a single integral part in the ram air fan assembly **10** of FIG. **1** and within the fan rotor **44** to replace the tie rod **40**, the shaft cap **38**, the journal bearing shaft **36** whereby the tie rod **210** extends along the axis Z, the journal bearing interface portion **208** interfaces with the journal bearings **42**, the openings **230** permit a flow of the cooling air **70** to proceed into an interior of the journal bearing shaft **200** and the heat exchange element **220** is disposed in the path of the cooling air **70**. The journal bearing shaft **200** can be additively manufactured using a metal such as stainless steel, a nickel-chromium-based superalloy (e.g., Inconel®) or any similar metal or combinations thereof that provide sufficient structural strength and a thermal pathway for heat to transfer from an adjacent electric motor to cooling air.

(19) With continued reference to FIG. **2** and with additional reference to FIG. **3**, the single monolithic body **201** of the journal bearing shaft **200** is formed as a single integral part for disposition in the ram air fan assembly **10** of FIG. **1**. In this way, the tie rod **210** extends forwardly along a central axis (i.e., axis Z of FIG. **1**) for a length L**1** that exceeds a total length L**2** of the journal bearing interface portion **208** and the heat exchange element **220**. An end **211** of the tie rod **210** integrally connects with the end cap **204**. The end cap **204** includes an inboard end cap portion **2041** and an outboard end cap portion **2042**. The inboard end cap portion **2041** extends radially outwardly from the tie rod **210**. The outboard end cap portion **2042** extends radially outwardly and aft from a distal edge of the inboard end cap portion **2041**. A distal edge of the outboard end cap portion **2042** integrally connects with the journal bearing interface portion **208**. The journal bearing interface portion **208** extends aft, is coaxial with the tie rod **210** and has an internal diameter D**1**. The heat exchange element **220** is integrally connected to and extends aft from an aft edge of the journal bearing interface portion **208** and is coaxial with the tie rod **210**. The exterior body **224** has an internal diameter D**2** that can be smaller than the internal diameter D**1**. The heat exchange fins **222** extend radially from an interior surface of the exterior body **224** to the tie rod **210**.

(20) With reference to FIG. **4** and in accordance with embodiments, the heat exchange fins **222** can have a lead angle of up to 45 degrees for example although it is to be understood that this lead angle can be increased or decreased as necessary. Also and in accordance with additional embodiments, a number of the heat exchange fins **222** can be variable (i.e., 24 heat exchange fins **222**, 12-64 heat exchange fins **222**, 12-32 heat exchange fins **222** as examples).

(21) With reference to FIG. **5** and in accordance with embodiments, one or more portions of the journal bearing shaft **200** can have a bi-metal structure. For example, as shown in FIG. **5**, the tie rod **210** and the exterior body **224** of the heat exchange element **220** can be formed of a first material such as one or more of stainless steel, Inconel™ or other similar materials or combinations thereof and the heat exchange fins **222** can be formed of a second material such as one or more of copper, nickel or nickel alloys (such as 200AM, In625 or other similar materials or combinations

thereof), corrosion resistant steel (17-4 or similar), aluminum alloys (A20× or similar), titanium or combinations thereof. In accordance with further embodiments, at least one or more of the tie rod **210**, the end cap **204** and the journal bearing interface portion **208** can be formed of the first material.

(22) The heat exchange fins **222** can be formed to define axial gaps to maintain a desired axial spacing between sets of heat exchange fins **222**. The heat exchange fins **222** can also be precisely placed, such that they are evenly distributed, and create an easily predictable flowpath and/or distributed at precise axial locations where heat transfer is desired without requiring the location to be directly accessible via an insert. In addition, the heat exchange fins **222** can include different features at different axial positions, including different thicknesses, different surface features, rotations and the like and without complexity of assembly. In addition, tighter tolerances afforded by additive manufacturing allow for more precisely evenly spaced heat exchange fins **222**, thereby improving a native balance of the journal bearing shaft **200** and minimizing the complexity and cost of a component balancing step.

(23) In addition, the additive manufacturing process to form the journal bearing shaft **200** can be utilized to incorporate additional non-castable features into various components, such as the heat exchange fins **222**. The non-castable features can be any physical structures that either could not be cast due to materials and existing technique limitations, could not be milled due to tooling limitations and/or would be cost prohibitive to create using existing casting and/or milling techniques. By way of example, internal features in tight tolerances are non-castable as even using expendable mold casting techniques as the material of the mold cannot be fully cleared out of the internal passages when the non-castable features are present. Furthermore, by additively manufacturing the journal bearing shaft **200** as a single integral part, the non-castable features can be included in less than the full length of the journal bearing shaft **200** and are not required to be distributed evenly along the axis Z.

(24) With reference to FIG. **6**, a method **600** of additively manufacturing a journal bearing shaft, such as the journal bearing shaft **200**, as a single monolithic body is provided. The method **600** includes building up a first tie rod portion in a layer-by-layer sequence by an additive manufacturing process such as laser powder bed fusion (PBF-L) or another similar process (block **601**). The method further includes simultaneously building up a second tie rod portion from the first tie rod portion and a heat exchange element about the second tie rod portion to include an exterior body and heat exchange fins extending radially between the second tie rod portion and the exterior body in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **602**), simultaneously building up a third tie rod portion from the second tie rod portion and a journal bearing interface portion from the heat exchange portion and about the third tie rod portion in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **603**) and simultaneously building up an end of the tie rod from the third tie rod portion and an end cap from the journal bearing interface portion to connect with the end of the tie rod in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **604**).

(25) In accordance with embodiments, the building up of the end cap of block **604** can include building up an inboard end cap portion to extend radially outwardly from the end of the tie rod and building up an outboard end cap portion from the journal bearing interface portion to extend radially outwardly and aft from a distal edge of the inboard end cap portion. Also, the building up of the heat exchange element and the second tie rod portion of block **602** is executed such that the heat exchange element and the second tie rod portion can be coaxial and the building up of the journal bearing interface portion and the third tie rod portion of block **603** are executed such that the journal bearing interface portion and the third tie rod portion can be coaxial. In addition, the building up of the heat exchange element and the journal bearing interface portion of block **602** and block **603** are executed such that an interior diameter of the heat exchange element can be smaller

than an interior diameter of the journal bearing interface portion.
(26) With reference to FIG. **7**, a method **700** of additively manufacturing a journal bearing shaft, such as the journal bearing shaft **200**, as a single monolithic body with a bi-metal construction is provided. The method **700** includes building up a first tie rod portion in a layer-by-layer sequence by an additive manufacturing process such as laser powder bed fusion (PBF-L) or another similar process (block **701**). The method further includes simultaneously building up a second tie rod portion from the first tie rod portion and a bi-metal heat exchange element about the second tie rod portion to include an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the second tie rod portion and the exterior body in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **702**), simultaneously building up a third tie rod portion from the second tie rod portion and a journal bearing interface portion from the bi-metal heat exchange portion and about the third tie rod portion in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **703**) and simultaneously building up an end of the tie rod from the third tie rod portion and an end cap from the journal bearing interface portion to connect with the end of the tie rod in a layer-by-layer sequence by an additive manufacturing process such as PBF-L or another similar process (block **704**).
(27) In accordance with embodiments, the building up of the end cap of block **704** can include building up an inboard end cap portion to extend radially outwardly from the end of the tie rod and building up an outboard end cap portion from the journal bearing interface portion to extend radially outwardly and aft from a distal edge of the inboard end cap portion. Also, the building up of the bi-metal heat exchange element and the second tie rod portion of block **702** is executed such that the bi-metal heat exchange element and the second tie rod portion can be coaxial and the building up of the journal bearing interface portion and the third tie rod portion of block **703** are executed such that the journal bearing interface portion and the third tie rod portion can be coaxial. In addition, the building up of the bi-metal heat exchange element and the journal bearing interface portion of block **702** and block **703** are executed such that an interior diameter of the bi-metal heat exchange element can be smaller than an interior diameter of the journal bearing interface portion.
(28) In accordance with further embodiments, the building up of the bi-metal heat exchanger of block **702** can include simultaneously feeding the first material and the second material into an additive manufacturing tool (block **7021**) or alternatively simultaneously feeding the first material into a first additive manufacturing tool and feeding the second material into a second additive manufacturing tool (block **7022**).
(29) Technical effects and benefits of the present disclosure are the provision of an additively manufactured integral shaft and motor rotor heat exchanger and tie rod for a ram air fan that can eliminate a need for expensive brazing of multiple details and that can maintain or be very close to thin wall thicknesses of sheet metal fins. The integral tie rod and end cap further reduce detail part count for improved cost, assembly time and improved quality/function as a single unit.
(30) The corresponding structures, materials, acts and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present disclosure has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the technical concepts in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiments were chosen and described in order to best explain the principles of the disclosure and the practical application and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.
(31) While the preferred embodiments to the disclosure have been described, it will be understood

that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the disclosure first described.

Claims

1. A journal bearing shaft, comprising: a single monolithic body, the single monolithic body comprising: a tie rod; an end cap integrally connected to and extending radially outwardly from an end of the tie rod and defining openings; a journal bearing interface portion integrally connected to and extending aft from a distal edge of the end cap; and a bi-metal heat exchanger integrally connected to and extending aft from an aft edge of the journal bearing interface portion and comprising an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the exterior body and the tie rod.
2. The journal bearing shaft according to claim 1, wherein a length of the tie rod exceeds a total length of the journal bearing interface portion and the bi-metal heat exchanger.
3. The journal bearing shaft according to claim 1, wherein the end cap comprises: an inboard end cap portion, which extends radially outwardly from the end of the tie rod; and an outboard end cap portion, which extends radially outwardly and aft from a distal edge of the inboard end cap portion.
4. The journal bearing shaft according to claim 1, wherein the journal bearing interface portion and the bi-metal heat exchanger are coaxial with the tie rod.
5. The journal bearing shaft according to claim 1, wherein an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.
6. The journal bearing shaft according to claim 1, wherein at least one or more of the tie rod, the end cap and the journal bearing interface portion is formed of the first material.
7. The journal bearing shaft according to claim 1, wherein the second material is one or more of copper, nickel or nickel alloys, corrosion resistant steel, aluminum alloys and titanium.
8. A ram air fan assembly, comprising: a fan rotor to move air from a fan inlet to a fan outlet; and a journal bearing shaft disposed as a single monolithic body within the fan rotor and defining a flow path for cooling air, the single monolithic body comprising: a tie rod; an end cap integrally connected to and extending radially outwardly from an end of the tie rod and defining openings; a journal bearing interface portion integrally connected to and extending aft from a distal edge of the end cap; and a bi-metal heat exchanger integrally connected to and extending aft from an aft edge of the journal bearing interface portion and comprising an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the exterior body and the tie rod.
9. The ram air fan assembly according to claim 8, wherein a length of the tie rod exceeds a total length of the journal bearing interface portion and the bi-metal heat exchanger.
10. The ram air fan assembly according to claim 8, wherein the end cap comprises: an inboard end cap portion, which extends radially outwardly from the end of the tie rod; and an outboard end cap portion, which extends radially outwardly and aft from a distal edge of the inboard end cap portion.
11. The ram air fan assembly according to claim 8, wherein the journal bearing interface portion and the bi-metal heat exchanger are coaxial with the tie rod.
12. The ram air fan assembly according to claim 8, wherein an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.
13. The ram air fan assembly according to claim 8, wherein at least one or more of the tie rod, the end cap and the journal bearing interface portion is formed of the first material.
14. The ram air fan assembly according to claim 8, wherein the second material is one or more of copper, nickel or nickel alloys, corrosion resistant steel, aluminum alloys and titanium.
15. A method of additively manufacturing a journal bearing shaft as a single monolithic body with

a bi-metal construction, the method comprising: building up a first tie rod portion; simultaneously building up a second tie rod portion from the first tie rod portion and a bi-metal heat exchanger about the second tie rod portion to comprise an exterior body formed of a first material and heat exchange fins formed of a second material differing from the first material and extending radially between the second tie rod portion and the exterior body; simultaneously building up a third tie rod portion from the second tie rod portion and a journal bearing interface portion from the bi-metal heat exchange portion and about the third tie rod portion; and simultaneously building up an end of the tie rod from the third tie rod portion and an end cap from the journal bearing interface portion to connect with the end of the tie rod.

16. The method according to claim 15, wherein the building up of the end cap comprises: building up an inboard end cap portion to extend radially outwardly from the end of the tie rod; and building up an outboard end cap portion from the journal bearing interface portion to extend radially outwardly and aft from a distal edge of the inboard end cap portion.

17. The method according to claim 15, wherein: the building up of the bi-metal heat exchanger and the second tie rod portion is executed such that the bi-metal heat exchanger and the second tie rod portion are coaxial, and the building up of the journal bearing interface portion and the third tie rod portion are executed such that the journal bearing interface portion and the third tie rod portion are coaxial.

18. The method according to claim 15, wherein the building up of the bi-metal heat exchanger and the journal bearing interface portion are executed such that an interior diameter of the bi-metal heat exchanger is smaller than an interior diameter of the journal bearing interface portion.

19. The method according to claim 15, wherein the building up of the bi-metal heat exchanger comprises simultaneously feeding the first material and the second material into an additive manufacturing tool.

20. The method according to claim 15, wherein the building up of the bi-metal heat exchanger comprises simultaneously feeding the first material into a first additive manufacturing tool and feeding the second material into a second additive manufacturing tool.