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HARMONIC GEAR SYSTEMS HAVING REDUNDANT LOAD PATHS BETWEEN INPUT AND OUTPUT SHAFTS

Abstract

A harmonic gear system, having: a housing; an input shaft having an aft end within the housing that defines a wave generator; a wave generator bearing; first and second nested cup-shaped flex splines that are grounded to the housing, the first and second flex splines are biased by the wave generator via the wave generator bearing; an output shaft having a forward end that is within the housing, and a radial flange at the forward end; first and second nested circular splined shafts within the housing, the first and second circular splined shafts are connected to the radial flange of the output shaft and are driven by ones of the first and second flex splines, to thereby drive the output shaft; and a bearing between the first and second circular splined shafts.

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Background/Summary

BACKGROUND

[0001] The embodiments are directed to harmonic gear systems and more specifically to harmonic gears systems having redundant load paths between input and output shafts.

[0002] To meet safety codes and standards, actuation systems such as found in aircrafts may require a dual load path (or drive paths) between an input shaft and an output shaft to provide redundancy and a lack of disconnect after a failure of one of the load paths.

BRIEF SUMMARY

[0003] Disclosed is a harmonic gear system, including: a housing having forward and aft ends; an input shaft having a forward end that is forward of the housing, and an aft end that is within the housing, wherein the aft end defines a wave generator; a wave generator bearing surrounding the wave generator; first and second cup-shaped flex splines, wherein the second flex spline is nested within the first flex spline, and the first and second flex splines are grounded to the forward end of the housing, and the first and second flex splines are simultaneously biased by the wave generator via the wave generator bearing; an output shaft having a forward end that is within the housing and an aft end that is aft of the housing, and a radial flange at the forward end; first and second circular splined shafts, within the housing, wherein the second circular splined shaft is nested within the first circular splined shaft, and the first and second circular splined shafts are connected to the radial flange of the output shaft and are driven by ones of the first and second flex splines, to thereby drive the output shaft; and a bearing between the first and second circular splined shafts.

[0004] In addition to one or more aspects of the system, or as an alternate, the wave generator extends from a forward end to an aft end; the first flex spline has: a forward end that is connected to the forward end of the housing; and an aft end, axially located at the forward end of the wave generator, that has an outer surface that is splined and an inner surface that is biased by the forward end of the wave generator; and the second flex spline has: a forward end that is connected to the forward end of the housing; and an aft end, axially located at the aft end of the wave generator, that has an outer surface that is splined, and an inner surface that is biased by the aft end of the wave generator.

[0005] In addition to one or more aspects of the system, or as an alternate, the first flex spline includes: a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the first flex spline; and the second flex spline includes: a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the second flex spline.

[0006] In addition to one or more aspects of the system, or as an alternate, the base of the first flex spline is secured to the forward end of the housing; and the base of the second flex spline is secured to the forward end of the housing via the base of the first flex spline; and the second flex spline is axially longer than the first flex spline, so that the aft ends of the first and second flex splines are axially adjacent to each other.

[0007] In addition to one or more aspects of the system, or as an alternate, the first circular splined shaft includes: a forward end that is axially located at the aft end of the first flex spline, wherein the forward end of the first circular splined shaft has an inner surface that is splined and engages the spline of the aft end of the first flex spline; and an aft end connected to the radial flange of the output shaft; and the second circular splined shaft includes: a forward end that is axially located at the aft end of the second flex spline, wherein the forward end of the second circular splined shaft has an inner surface that is splined and engages the spline of the aft end of the second flex spline; and an aft end connected to the radial flange of the output shaft.

[0008] In addition to one or more aspects of the system, or as an alternate, the second circular splined shaft is longer than the first circular splined shaft, so that the forward ends of the first and second circular splined shafts are axially adjacent to each other.

[0009] In addition to one or more aspects of the system, or as an alternate, the system further includes a radial inner flange at the forward end of the first circular splined shaft, wherein the radial inner flange has the inner surface that is splined.
[0010] In addition to one or more aspects of the system, or as an alternate, the wave generator bearing extends from a forward end to an aft end; and the forward and aft ends of the wave generator bearing are clipped to the forward and aft ends of the wave generator.
[0011] In addition to one or more aspects of the system, or as an alternate, the system further includes forward roller bearings between the forward end of the input shaft and the forward end of the housing; aft roller bearings between the output shaft and the aft end of the housing; first inner roller bearings between the forward end of the first circular splined shaft and the housing; second inner roller bearings between the aft end of the first circular splined shaft and the housing; and third inner roller bearings between the aft end of the input shaft and the second circular splined shaft.
[0012] Disclosed is another harmonic gear system, including: a housing having forward and aft ends; an input shaft having a forward end that is forward of the housing, and an aft end that is within the housing, wherein the aft end defines a wave generator; a wave generator bearing surrounding the wave generator; a cup-shaped flex spline, grounded to the forward end of the housing, having first and second splines which are simultaneously biased by the wave generator via the wave generator bearing; an output shaft having a forward end that is within the housing and an aft end that is aft of the housing, and a radial flange at the forward end; first and second circular splined shafts, within the housing, wherein the second circular splined shaft is nested within the first circular splined shaft, and the first and second circular splined shafts are connected to the radial flange of the output shaft and are driven by ones of the first and second splines of the flex spline, to thereby drive the output shaft; and a bearing between the first and second circular splined shafts.
[0013] In addition to one or more aspects of the another system, or as an alternate, the system further includes the wave generator extends from a forward end to an aft end; and the flex spline includes: a forward end that is connected to the forward end of the housing; and an aft end that has an outer surface that has the first and second splines such that the first spline is axially located at the forward end of the wave generator and the second spline is axially located at the aft end of the wave generator, and an inner surface that is biased by the wave generator.
[0014] In addition to one or more aspects of the another system, or as an alternate, the flex spline includes a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the flex spline.
[0015] In addition to one or more aspects of the another system, or as an alternate, the base of the flex spline is secured to the forward end of the housing.
[0016] In addition to one or more aspects of the another system, or as an alternate, the first circular splined shaft includes: a forward end that is axially located at the first spline of the flex spline, wherein the forward end of the first circular splined shaft has an inner surface that is splined and engages the first spline of the flex spline; and an aft end connected to the radial flange of the output shaft; and the second circular splined shaft includes: a forward end that is axially located at the second spline of the flex spline, wherein the forward end of the second circular splined shaft has an inner surface that is splined and engages the second spline of the flex spline; and an aft end connected to the radial flange of the output shaft.
[0017] In addition to one or more aspects of the another system, or as an alternate, the second circular splined shaft is longer than the first circular splined shaft, so that the forward ends of the first and second circular splined shafts are axially adjacent to each other.
[0018] In addition to one or more aspects of the another system, or as an alternate, the system includes a radial inner flange at the forward end of the first circular splined shaft, wherein the radial inner flange has the inner surface that is splined.

[0019] In addition to one or more aspects of the another system, or as an alternate, the wave generator bearing extends from a forward end to an aft end; and the forward and aft ends of the wave generator bearing are clipped to the forward and aft ends of the wave generator.
[0020] In addition to one or more aspects of the another system, or as an alternate, the system includes forward roller bearings between the forward end of the input shaft and the forward end of the housing; aft roller bearings between the output shaft and the aft end of the housing; first inner roller bearings between the forward end of the first circular splined shaft and the housing; second inner roller bearings between the aft end of the first circular splined shaft and the housing; and third inner roller bearings between the aft end of the input shaft and the second circular splined shaft.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0021] The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements.
[0022] FIG. **1** shows an aircraft according to an embodiment;
[0023] FIG. **2** shows a harmonic gear system having redundant flex splines, and an output shaft with redundant circular splined shafts, according to an embodiment;
[0024] FIG. **3** shows a detail of the harmonic gear system of FIG. **2**;
[0025] FIG. **4** shows, in isolation, from the system of FIG. of FIG. **2**, the input shaft, the redundant flex splines, and the output shaft with the redundant circular splined shafts;
[0026] FIG. **5** identifies additional aspects of the harmonic gear system of FIG. **2**, including bearings and a configuration of the system housing;
[0027] FIG. **6** shows a harmonic gear system having a flex spline with redundant splines, and an output shaft with redundant circular splined shafts, according to an embodiment;
[0028] FIG. **7** shows a detail of the harmonic gear system of FIG. **6**;
[0029] FIG. **8** shows, in isolation, from the system of FIG. of FIG. **6**, the input shaft, the flex spline with redundant splines, and the output shaft with the redundant circular splined shafts; and
[0030] FIG. **9** identifies additional aspects of the harmonic gear system of FIG. **6**, including bearings and a configuration of the system housing.
DETAILED DESCRIPTION
[0031] FIG. **1** shows an aircraft **1** having a fuselage **2** with a wing **3** and tail assembly **4**, which may have control surfaces **5**. The wing **3** may include an engine **6**, such as a gas turbine engine, and an auxiliary power unit **7** may be disposed at the tail assembly **4**. Movable parts such as the control surfaces **5** may be moved by a motor **10** via a drive such as a gear system **100**. Disclosed herein are gear systems **100** that are harmonic gear systems having redundant load paths between an input shaft **120** and an output shaft **160**. The disclosed systems provide redundancy and a lack of disconnect if there a failure of one of the load paths.
[0032] Turning generally to FIG. **2**, a harmonic (or strain wave) gear system **100** is disclosed according to an embodiment. The system **100** includes a housing **110** extending along an axis **115** (or axial direction, extending forward **115**A and aft **115**B) between forward and aft ends **112**, **114**. An input shaft **120** has a forward end **122** that is forward (outside) of the housing **110**, and an aft end **124** that is within the housing **110**. An output shaft **160** has a forward end **162** that is within the housing **110** and an aft end **164** that is aft (outside) of the housing **110**.
[0033] As shown in FIG. **3**, the aft end **124** of the input shaft **120** defines a wave generator **130** that extends from forward to aft ends **132**, **134**. A wave generator bearing **140** surrounds the wave generator **130**. The wave generator bearing **140** extends from a forward end **142** to an aft end **144**. The forward and aft ends **142**, **144** of the wave generator bearing **140** are clipped to the forward and aft ends **132**, **134** of the wave generator **130**.

[0034] The system **100** includes first and second cup-shaped flex splines **150**A, **150**B (generally **150**). The second flex spline **150**B is nested in the first flex spline **150**A. The first and second flex splines **150** are grounded to the forward **112** end of the housing **110**. The first and second flex splines **150** are simultaneously biased (flexed) by the wave generator **130** via the wave generator bearing **140**.

[0035] More specifically, the first flex spline **150**A has a forward end **152**A that is connected to the forward end **112** of the housing **110**. The first flex spline **150**A has an aft end **154**A that is axially located at the forward end **132** of the wave generator **130**. The aft end **154**A of the first flex spline **150**A has an outer surface **155**A (FIG. **4**) that is splined **157**A and an inner surface **156**A that is biased by the forward end **132** of the wave generator **130**.

[0036] The first flex spline **150**A includes a radially extending base **190**A at the forward end **152**A that defines a center aperture **153**A through which the input shaft **120** extends. The first flex spline **150**A includes an axially extending wall **200**A that extends aft from the base **190**A to the aft end **154**A of the first flex spline **150**A. The base **190**A of the first flex spline **150**A is secured to the forward end **112** of the housing **110**.

[0037] The second flex spline **150**B has a forward end **152**B that is connected to the forward end **112** of the housing **110**. The second flex spline **150**B has an aft end **154**B that is axially located at the aft end **134** of the wave generator **130**. The aft end **154**B of the second flex spline **150**B has an outer surface **155**B (FIG. **4**) that is splined **157**B and an inner surface **156**B that is biased by the aft end **134** of the wave generator **130**. The configuration of the splines **157**A, **157**B are substantially the same as each other.

[0038] The second flex spline **150**B includes a radially extending base **190**B at the forward end **152**B that defines a center aperture **153**B through which the input shaft **120** extends. The second flex spline **150**B includes an axially extending wall **200**B that extends aft from the base **190**B to the aft end **154**B of the second flex spline. It is to be appreciated that the wall **200**B of the second flex spline **150**B, which is flexible, extends between the aft end **154**A of the first spline **150** and the wave generator bearing **140**. The base **190**A of the second flex spline **150**B is secured to the forward end **112** of the housing **110** via the base **190**A of the first flex spline **150**A.

[0039] The second flex spline **150**B is axially longer than the first flex spline **150**A. With this configuration, the aft ends **154**A, **154**B of the first and second flex splines **150** are axially adjacent to each other.

[0040] As shown in FIG. **4**, a radial flange **170** is located at the forward end **162** of the output shaft **160**. The system **100** includes first and second circular splined shafts **180**A, **180**B (generally **180**) within the housing **110** (FIG. **2**). The second circular splined shaft **180**B is nested within the first circular splined shaft **180**A. The first and second circular splined shafts **180** are connected to the radial flange **170** of the output shaft **160** and are driven by ones of the first and second flex splines **150**. With this configuration, driving the first and second circular splined shafts **180** results in driving the output shaft **160**.

[0041] The first circular splined shaft **180**A has a forward end **182**A that is axially located at the aft end **154**A of the first flex spline **150**A. The forward end **182**A of the first circular splined shaft **180**A has an inner surface **186**A that is splined and engages the spline of the aft end **154**A of the first flex spline **150**A. The first circular splined shaft **180**A has an aft end **184**A connected to the radial flange **170** of the output shaft **160**.

[0042] The second circular splined shaft **180**B has a forward end **182**A that is axially located at the aft end **184**B of the second flex spline. The forward end **182**B of the second circular splined shaft **180**B has an inner surface **186**B that is splined and engages the spline of the aft end **184**B of the second flex spline. The second circular splined shaft **180**B has an aft end **184**B connected to the radial flange **170** of the output shaft **160**. The configuration of the splines of the are circular splined shafts **180**A, **180**B are substantially the same as each other.

[0043] The second circular splined shaft **180**B is longer than the first circular splined shaft. With

this configuration, the forward ends **182**A, **182**B of the first and second circular splined shafts **180** are axially adjacent to each other.

[0044] A radial inner flange **185** is located at the forward end **182**A of the first circular splined shaft. The radial inner flange **185** has the inner surface **186**A of the first circular splined shaft **180**A that is splined. With the inner flange **185**, the first circular splined shaft **180** is cup-shaped.

[0045] A bearing **188**, which may be a roller bearing, a plain bearing or a bushing as non-limiting examples, is between the first and second circular splined shafts **180**. This prevents frictional binding between the first and second circular splined shafts **180** if one of the load paths breaks.

[0046] Turning to FIG. **5**, forward roller bearings **210** are located between the forward end **122** of the input shaft **120** and the forward end **112** of the housing **110**. aft roller bearings **220** are located between the output shaft **160** and the aft end **114** of the housing **110**. First inner roller bearings **230** are located between the forward end **182**A of the first circular splined shaft **180**A and the housing **110**. Second inner roller bearings **240** are located between the aft end **184**A of the first circular splined shaft **180**A and the housing **110**. Third inner roller bearings **250** between the aft end **124** of the input shaft **120** and the second circular splined shaft **180**B.

[0047] The flex splines **150** may be secured to the forward end **112** of the housing via forward fasteners **260**, which may be bolts. The circular splined shafts **180** may be secured to the output shaft **160** via aft fasteners **270**, which also may be bolts. The housing **110** may be formed of forward and aft sections **116**, **117**, which may be secured together via housing fasteners **275**, which may also be bolts. The housing **110** may define a cavity **118** with forward and aft apertures **119**A, **119**B through which the input and output shafts **120**, **160** extend. End surfaces **121**A, **121**B that define the apertures **119**A, **119**B may be utilized as radial seats for the forward and aft bearings **210**, **220**. An interior surface **121**C that defines the cavity **118** may be utilized as a seat for the first and second inner bearings **230**, **240**. Axially facing apertures **121**D in the forward end **112** of the housing **110** may be utilized for mounting the housing **110** to a stationary structure, e.g., in an aircraft **1** (FIG. **1**). Forward and aft inner housing walls **123**A, **123**B may encase the cavity **118** and be utilized as axial seats for the forward and aft bearings **210**, **220**. The forward and aft inner housing walls **123**A, **123**B may define inner housing apertures **123**C, **123**D through which the input and output shafts **120**, **160** extend. The flex splines **150** may be secured to the forward inner housing wall **123**A with forward fasteners **260**.

[0048] In the above embodiments, each respective pair of flex splines **150** and circular splined shafts **180** defines a load path between the input shaft **120** and the output shaft **160**. The above embodiment provides a harmonic gear system **100** with redundant flex splines **150**, driven by an input shaft **120**, that engage redundant circular splined shafts connected to an output shaft **160**. Benefits include the removal of the possibility of a disconnect between input and output shaft **160** after failure of one the flex splines **150** or one of the circular splined shaft **180**. Turning to FIG. **6**, a harmonic (or strain wave) gear system **100** is disclosed according to another embodiment. The system **100** includes a housing **110** extending along an axis **115** (or axial direction, extending forward **115**A and aft **115**B) between forward and aft ends **112**, **114**. An input shaft **120** has a forward end **122** that is forward of the housing **110**, and an aft end **124** that is within the housing **110**. An output shaft **160** has a forward end **162** that is within the housing **110** and an aft end **164** that is aft of the housing **110**.

[0049] As shown in FIG. **7**, the aft end **124** of the input shaft **120** defines a wave generator **130** that extends from forward to aft ends **132**, **134**. The wave generator bearing **140** extends from a forward end **142** to an aft end **144**. The forward and aft ends **142**, **144** of the wave generator bearing **140** are clipped to the forward and aft ends **132**, **134** of the wave generator **130**.

[0050] The system **100** includes a cup-shaped flex spline **150**. The flex spline **150** is grounded to the forward end **112** of the housing **110**. The flex spline **150** has first and second splines **157**A, **157**B (generally **157**) (FIG. **8**), which are simultaneously biased by the wave generator **130** via the wave generator bearing **140**.

[0051] More specifically, the flex spline **150** has a forward end **152** that is connected to the forward end **112** of the housing **110**. The flex spline **150** has an aft end **154** that has an outer surface **155** (FIG. **8**). The outer surface **155** has the first and second splines **157**A, **157**B. The first spline **157**A is axially located at the forward end **132** of the wave generator **130** and the second spline **157**B is axially located at the aft end **134** of the wave generator **130**. The configuration of the splines **157**A, **157**B are substantially the same as each other. The flex spline **150** has an inner surface **156** that is biased by the wave generator **130**.
[0052] The flex spline **150** includes a radially extending base **190** at the forward end **152** that defines a center aperture **153** through which the input shaft **120** extends. The flex spline **150** includes an axially extending wall **200** that extends aft from the base **190** to the aft end **154** of the flex spline. The base **190** of the flex spline **150** is secured to the forward end **112** of the housing **110**.
[0053] As shown in FIG. **8**, a radial flange **170** is located at the forward end **162** of the output shaft **160**. The system **100** includes first and second circular splined shafts **180**A, **180**B (generally **180**) within the housing **110** (FIG. **6**). The second circular splined shaft **180**B is nested within the first circular splined shaft. The first and second circular splined shafts **180** are connected to the radial flange **170** of the output shaft **160** and are driven by ones of the first and second splines **157** of the flex spline **150**. With this configuration, driving the first and second circular splined shafts **180** results in driving the output shaft **160**.
[0054] The first circular splined shaft **180**A has a forward end **182**A that is axially located at the first spline **157**A of the flex spline. The forward end **182**A of the first circular splined shaft **180**A has an inner surface **186**A that is splined and engages the first spline **157**A of the flex spline. The first circular splined shaft **180**A has an aft end **184**A that is connected to the radial flange **170** of the output shaft **160**.
[0055] The second circular splined shaft **180**B has a forward end **184**B that is axially located at the second spline **157**B of the flex spline. The forward end **182**B of the second circular splined shaft **180**B has an inner surface **186**B that is splined and engages the second spline **157**B of the flex spline. An aft end **184**B of the second circular splined shaft **180**B is connected to the radial flange **170** of the output shaft **160**. The configuration of the splines of the are circular splined shafts **180**A, **180**B are substantially the same as each other.
[0056] The second circular splined shaft **180**B is longer than the first circular splined shaft. With this configuration, the forward ends **182**A, **182**B of the first and second circular splined shafts **180** are axially adjacent to each other.
[0057] A radial inner flange **185** is located at the forward end **182**A of the first circular splined shaft. The radial inner flange **185** has the inner surface **186**A of the first circular splined shaft **180**A that is splined.
[0058] A bearing **188** is between the first and second circular splined shafts **180**. This prevents frictional binding between the first and second circular splined shafts **180** if one of the load paths breaks.
[0059] Turning to FIG. **9**, forward roller bearings **210** are located between the forward end **122** of the input shaft **120** and the forward end **112** of the housing **110**. aft roller bearings **220** are located between the output shaft **160** and the aft end **114** of the housing **110**. First inner roller bearings **230** are located between the forward end **182**A of the first circular splined shaft **180**A and the housing **110**. Second inner roller bearings **240** are located between the aft end **184**A of the first circular splined shaft **180**A and the housing **110**. Third inner roller bearings **250** between the aft end **124** of the input shaft **120** and the second circular splined shaft **180**B.
[0060] The flex splines **150** may be secured to the forward end **112** of the housing via forward fasteners **260**, which may be bolts. The circular splined shafts **180** may be secured to the output shaft **160** via aft fasteners **270**, which also may be bolts. The housing **110** may be formed of forward and aft sections **116**, **117**, which may be secured together via housing fasteners **275**, which

may also be bolts. The housing **110** may define a cavity **118** with forward and aft apertures **119**A, **119**B through which the input and output shafts **120**, **160** extend. End surfaces **121**A, **121**B that define the apertures **119**A, **119**B may be utilized as radial seats for the forward and aft bearings **210**, **220**. An interior surface **121**C that defines the cavity **118** may be utilized as a seat for the first and second inner bearings **230**, **240**. Axially facing apertures **121**D in the forward end **112** of the housing **110** may be utilized for mounting the housing **110** to a stationary structure, e.g., in an aircraft **1** (FIG. **1**). Forward and aft inner housing walls **123**A, **123**B may encase the cavity **118** and be utilized as axial seats for the forward and aft bearings **210**, **220**. The forward and aft inner housing walls **123**A, **123**B may define inner housing apertures **123**C, **123**D through which the input and output shafts **120**, **160** extend. The flex spline **150** may be secured to the forward inner housing wall **123**A via the forward fasteners **260**.

[0061] In the above embodiments, each respective pair of splines **157** of the flex spline **150** and circular splined shafts **180** defines a load path between the input shaft **120** and the output shaft **160**. The above embodiment provides a harmonic gear system **100** with a flex spline having redundant splines, driven by an input shaft **120**, that engage redundant circular splined shafts of an output shaft **160**. Benefits include the removal of the possibility of a disconnect between input and output shaft **160** after failure of one the circular splined shafts **180**.

[0062] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0063] Those of skill in the art will appreciate that various example embodiments are shown and described herein, each having certain features in the particular embodiments, but the present disclosure is not thus limited. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions, combinations, sub-combinations, or equivalent arrangements not heretofore described, but which are commensurate with the scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments. Accordingly, the present disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A harmonic gear system, comprising: a housing having forward and aft ends; an input shaft having a forward end that is forward of the housing, and an aft end that is within the housing, wherein the aft end defines a wave generator; a wave generator bearing surrounding the wave generator; first and second cup-shaped flex splines, wherein the second flex spline is nested within the first flex spline, and the first and second flex splines are grounded to the forward end of the housing, and the first and second flex splines are simultaneously biased by the wave generator via the wave generator bearing; an output shaft having a forward end that is within the housing and an aft end that is aft of the housing, and a radial flange at the forward end; first and second circular splined shafts, within the housing, wherein the second circular splined shaft is nested within the first circular splined shaft, and the first and second circular splined shafts are connected to the radial flange of the output shaft and are driven by ones of the first and second flex splines, to thereby drive the output shaft; and a bearing between the first and second circular splined shafts.

2. The system of claim 1, wherein: the wave generator extends from a forward end to an aft end; the first flex spline has: a forward end that is connected to the forward end of the housing; and an

aft end, axially located at the forward end of the wave generator, that has an outer surface that is splined and an inner surface that is biased by the forward end of the wave generator; and the second flex spline has: a forward end that is connected to the forward end of the housing; and an aft end, axially located at the aft end of the wave generator, that has an outer surface that is splined, and an inner surface that is biased by the aft end of the wave generator.

3. The system of claim 2, wherein: the first flex spline includes: a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the first flex spline; and the second flex spline includes: a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the second flex spline.

4. The system of claim 3, wherein: the base of the first flex spline is secured to the forward end of the housing; and the base of the second flex spline is secured to the forward end of the housing via the base of the first flex spline; and the second flex spline is axially longer than the first flex spline, so that the aft ends of the first and second flex splines are axially adjacent to each other.

5. The system of claim 4, wherein the first circular splined shaft includes: a forward end that is axially located at the aft end of the first flex spline, wherein the forward end of the first circular splined shaft has an inner surface that is splined and engages the spline of the aft end of the first flex spline; and an aft end connected to the radial flange of the output shaft; and the second circular splined shaft includes: a forward end that is axially located at the aft end of the second flex spline, wherein the forward end of the second circular splined shaft has an inner surface that is splined and engages the spline of the aft end of the second flex spline; and an aft end connected to the radial flange of the output shaft.

6. The system of claim 5, wherein the second circular splined shaft is longer than the first circular splined shaft, so that the forward ends of the first and second circular splined shafts are axially adjacent to each other.

7. The system of claim 6, further including a radial inner flange at the forward end of the first circular splined shaft, wherein the radial inner flange has the inner surface that is splined.

8. The system of claim 7, wherein: the wave generator bearing extends from a forward end to an aft end; and the forward and aft ends of the wave generator bearing are clipped to the forward and aft ends of the wave generator.

9. The system of claim 8, further including: forward roller bearings between the forward end of the input shaft and the forward end of the housing; aft roller bearings between the output shaft and the aft end of the housing; first inner roller bearings between the forward end of the first circular splined shaft and the housing; second inner roller bearings between the aft end of the first circular splined shaft and the housing; and third inner roller bearings between the aft end of the input shaft and the second circular splined shaft.

10. A harmonic gear system, comprising: a housing having forward and aft ends; an input shaft having a forward end that is forward of the housing, and an aft end that is within the housing, wherein the aft end defines a wave generator; a wave generator bearing surrounding the wave generator; a cup-shaped flex spline, grounded to the forward end of the housing, having first and second splines which are simultaneously biased by the wave generator via the wave generator bearing; an output shaft having a forward end that is within the housing and an aft end that is aft of the housing, and a radial flange at the forward end; first and second circular splined shafts, within the housing, wherein the second circular splined shaft is nested within the first circular splined shaft, and the first and second circular splined shafts are connected to the radial flange of the output shaft and are driven by ones of the first and second splines of the flex spline, to thereby drive the output shaft; and a bearing between the first and second circular splined shafts.

11. The system of claim 10, wherein: the wave generator extends from a forward end to an aft end; and the flex spline includes: a forward end that is connected to the forward end of the housing; and

an aft end that has an outer surface that has the first and second splines such that the first spline is axially located at the forward end of the wave generator and the second spline is axially located at the aft end of the wave generator, and an inner surface that is biased by the wave generator.

12. The system of claim 11, wherein the flex spline includes: a radially extending base at the forward end that defines a center aperture through which the input shaft extends; and an axially extending wall that extends aft from the base to the aft end of the flex spline.

13. The system of claim 12, wherein the base of the flex spline is secured to the forward end of the housing.

14. The system of claim 13, wherein: the first circular splined shaft includes: a forward end that is axially located at the first spline of the flex spline, wherein the forward end of the first circular splined shaft has an inner surface that is splined and engages the first spline of the flex spline; and an aft end connected to the radial flange of the output shaft; and the second circular splined shaft includes: a forward end that is axially located at the second spline of the flex spline, wherein the forward end of the second circular splined shaft has an inner surface that is splined and engages the second spline of the flex spline; and an aft end connected to the radial flange of the output shaft.

15. The system of claim 14, wherein the second circular splined shaft is longer than the first circular splined shaft, so that the forward ends of the first and second circular splined shafts are axially adjacent to each other.

16. The system of claim 15, further including a radial inner flange at the forward end of the first circular splined shaft, wherein the radial inner flange has the inner surface that is splined.

17. The system of claim 16, wherein: the wave generator bearing extends from a forward end to an aft end; and the forward and aft ends of the wave generator bearing are clipped to the forward and aft ends of the wave generator.

18. The system of claim 17, further including: forward roller bearings between the forward end of the input shaft and the forward end of the housing; aft roller bearings between the output shaft and the aft end of the housing; first inner roller bearings between the forward end of the first circular splined shaft and the housing; second inner roller bearings between the aft end of the first circular splined shaft and the housing; and third inner roller bearings between the aft end of the input shaft and the second circular splined shaft.