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Three segment intermediated shaft

Abstract

An I-shaft assembly includes an upper shaft extending along an axis between a first upper end and a first lower end bounding a first hollow bore. An intermediate shaft extends along the axis between a second upper end and a second lower end bounding a second hollow bore. The second upper end is disposed in the first hollow bore. A lower shaft extends along the axis between a third upper end and a third lower end disposed in the second hollow bore. The upper shaft is releasably fixed for controlled movement along the axis relative to the intermediate shaft, and the lower shaft is releasably fixed against movement along the axis relative to the intermediate shaft during a normal operating condition. The upper shaft moves along the axis relative to the intermediate shaft and the lower shaft moves along the axis relative to the intermediate shaft during an abnormal operating condition.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This U.S. utility patent application claims priority to Chinese Patent Application No. 2024107250622 filed on Jun. 5, 2024, the content of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

(2) The present disclosure generally relates to intermediate shaft assemblies for motor vehicles, and more specifically, to an intermediate shaft assembly for a vehicle having three coaxial shafts connected to one another.

BACKGROUND OF THE INVENTION

(3) Intermediate shafts (I-shafts) are designed to be a component of torque transfer from a steering column to a steering gear. Known I-shafts have a pair of coaxial shafts connected to another. During a collapse event, such as in a vehicle crash, the pair of shafts can typically collapse relative to one another in telescoping fashion, such that length of the I-shaft decreases. With there being only two shafts, the length of collapse is limited, and in some modern applications, is less than desired.

SUMMARY OF THE INVENTION

(4) According to the objects, features and advantages, an aspect of the present disclosure provides

an I-shaft assembly. The I-shaft assembly includes an upper shaft extending along an axis between a first upper end and a first lower end. The first lower end has a first tubular wall portion with a first inner surface bounding a first hollow bore extending into the first lower end. An intermediate shaft extends along the axis between a second upper end and a second lower end. The second upper end has a first outer surface and the second lower end has a second tubular wall portion with a second inner surface bounding a second hollow bore extending into the second lower end. The second upper end is disposed in the first hollow bore. A lower shaft extends along the axis between a third upper end and a third lower end. The third upper end has a second outer surface disposed in the second hollow bore. The upper shaft is releasably fixed for controlled movement along the axis relative to the intermediate shaft, and the lower shaft is releasably fixed against movement along the axis relative to the intermediate shaft during a normal operating condition, whereat a maximum axial force is applied along the axis during the normal operating condition. The upper shaft moves along the axis relative to the intermediate shaft and the lower shaft moves along the axis relative to the intermediate shaft during an abnormal operating condition, whereat an axial force greater than the maximum axial force is applied along the axis during the abnormal operating condition.
(5) In accordance with another aspect of the present disclosure, a method of assembling an intermediate shaft assembly includes: providing an upper shaft extending along an axis between a first upper end and a first lower end, with the first lower end having a first tubular wall portion with a first inner surface bounding a first hollow bore extending into the first lower end. Further, providing an intermediate shaft extending along the axis between a second upper end and a second lower end, the second upper end having a first outer surface and the second lower end having a second tubular wall portion with at least one through opening passing radially therethrough, the second tubular wall portion having a second inner surface bounding a second hollow bore extending into the second lower end. Further, providing a lower shaft extending along the axis between a third upper end and a third lower end, the third upper end having a second outer surface with at least one recess extending radially therein. Further yet, disposing the second upper end in the first hollow bore and releasably fixing the upper shaft for controlled movement along the axis relative to the intermediate shaft during the normal operating condition. Further yet, disposing the third upper end in the second hollow bore with the at least one through opening being radially aligned with the at least one recess, and injecting polymeric material into at least one of the at least one through opening and into the at least one recess and allowing the polymeric material to solidify within the at least one through opening and within the at least one recess to fix the lower shaft against movement along the axis relative to the intermediate shaft during the normal operating condition. The polymeric material is configured to shear under a predetermined axial load to allow the lower shaft to move along the axis relative to the intermediate shaft during an abnormal operating condition.
(6) These and other objects, advantages and features will become more apparent to one possessing ordinary skill in the art from the following description taken in conjunction with the drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:
(2) FIG. **1** is a perspective view of a motor vehicle having an I-shaft constructed in accordance with one aspect of the disclosure;
(3) FIG. **2** is a longitudinal cross-sectional view taken off-center from a central longitudinal axis of

the I-shaft assembly shown in FIG. **1**, with the I-shaft assembly shown in a fully assembled, extended, normal operating state;

(4) FIG. **3** is a side view of the I-shaft assembly as shown in FIG. **2**, with the I-shaft rotated to illustrate injection through openings extending through an intermediate shaft through which polymeric material is injected to releasably fix the intermediate shaft to a lower shaft;

(5) FIG. **4** is a view similar to FIG. **2**, with the I-shaft assembly shown in a fully collapsed, abnormal operating state;

(6) FIG. **5** is an explode perspective view of the I-shaft assembly of FIGS. **2-4**;

(7) FIG. **6** is a fragmentary, partially sectioned perspective view of the I-shaft assembly of FIGS. **2-3**, with a portion of the polymeric material removed from a recess in the lower shaft for clarity purposes only; and

(8) FIG. **7** is a cross-sectional view taken generally along the line **7-7** of FIG. **6**.

DETAILED DESCRIPTION

(9) Referring now to the Figures, where the invention will be described in greater detail with reference to specific embodiments, without limitation, FIG. **1** illustrates a motor vehicle **10** having an I-shaft assembly **12**, constructed in accordance with one aspect of the disclosure for operably coupling a steering wheel **14** to a steering rack or gear **16**. As discussed hereafter, the I-shaft **12** includes three shafts coaxially aligned with one along a common central longitudinal axis **18**. The I-shaft assembly **12** provides optimal steering performance during a normal operating condition, whereat the length of the I-shaft assembly **12** remains substantially unchanged, with exception of a possible small axial movement between two of the shafts, while also providing an optimal ability of the I-shaft **12** to collapse axially during an abnormal operating condition, such as a crash condition, whereat the three shafts are able to collapse telescopically relative to one another along the central longitudinal axis **18**. With the ability of the three shafts to collapse, an increased capacity of axial collapse is provided, thereby minimizing a potential of harm to a driver.

(10) The I-shaft assembly **12** is a three segment assembly, including an upper shaft **20** extending along the central longitudinal axis, referred to hereafter as axis **18**, between a first upper end **22** and a first lower end **24**. The first lower end **24** has a first tubular wall portion **26** with a first inner surface **28** bounding a first hollow bore **29** extending into the first lower end **24**. An intermediate shaft **30** extends along the axis **18** between a second upper end **32** and a second lower end **34**. The second upper end **32** has a first outer surface **36** and the second lower end **34** has a second tubular wall portion **38** with a second inner surface **40** bounding a second hollow bore **42** extending into the second lower end **34**. The second upper end **32** is disposed in the first hollow bore **29**. A lower shaft **44** extends along the axis **18** between a third upper end **46** and a third lower end **48**. The third upper end **46** has a second outer surface **50** disposed in the second hollow bore **42**. The upper shaft **20** is releasably fixed for controlled movement along the axis **18** relative to the intermediate shaft **30**, and the lower shaft **44** is releasably fixed against movement along the axis **18** relative to the intermediate shaft **30** during a normal operating condition, whereat a maximum axial force F**1** is applied along the axis **18** during the normal operating condition. The upper shaft **20** moves along the axis **18** relative to the intermediate shaft **30** and the lower shaft **44** moves along the axis **18** relative to the intermediate shaft **30** during an abnormal operating condition, such as a crash condition, whereat an axial force F**2** greater than the maximum axial force F**1** is applied along the axis **18** during the abnormal operating condition.

(11) FIG. **2** illustrates an exploded view exploded generally along the central longitudinal axis **18** of the I-shaft assembly shown in FIG. **1**. The central longitudinal axis **18** is a common central longitudinal axis for each of the upper shaft **20**, the intermediate shaft **30** and the lower shaft **44**, such the respective shafts **20**, **30**, **44** are coaxially aligned with one another.

(12) The upper shaft **20**, in the embodiment shown, by way of example and without limitation, is a purely tubular member, such that the first hollow bore **29** extends along the entire length of upper shaft **20**, such that upper shaft **20** can be readily extruded and subsequently shaped, if desired.

Accordingly, the first hollow bore **29** extends from the first upper end **22** to the first lower end **24**. The first inner surface **28** of the upper shaft **20** has a plurality of radially inwardly extending first female splines **52**. The first female splines **52** extend parallel to the axis **18**. In the illustrated non-limiting embodiment, the first female splines **52** extend from the first lower end **24** along the substantial full length adjacent to the first upper end **22**, with "substantial" meaning that the first female splines **52** extend nearly to the first upper end **22**, but stop just short, such as by about 1-3 inches, of the first upper end **22**, with the region of the first inner surface **28** not having the first female spines **52** having a slightly enlarged diameter relative to the first outer surface **36** of the intermediate shaft **30**. Accordingly, in the abnormal operating condition, whereupon the I-shaft assembly **12** has collapsed axially, none, or very slight friction is imparted against the first outer surface **36** in the enlarged diameter region. The number of first female splines **52** can be provided as desired for the intended application, end in one non-limiting embodiment, having 48 teeth, to provide the desired friction between the upper shaft **20** and the intermediate shaft **30**, thereby allowing controlled axial movement therebetween, such as may be desired during normal operating condition, such as during turning maneuvers, for example.

(13) The intermediate shaft **30** extends along the axis **18** between the second upper end **32** and the second lower end **34**. The first outer surface **36** has a plurality of radially outwardly extending first male splines **54** interdigitated with the first female splines **52**. The first male splines **54** of the non-limiting embodiment extend from the second upper end **32** toward the second lower end **34**, such that the first male splines **54** are fully received for engagement with the first female splines **52** upon assembly of the intermediate shaft **30** to the lower shaft **20**. The first male splines **54** are shown as extending along about ⅓ the length of the intermediate shaft **30**, by way of example and without limitation. To enhance performance between the intermeshed first female splines **52** and first male splines **54**, such as to attain a desired relative slide performance, to reduce noise and vibration, and to enhanced wear properties and performance, a polyamide coating **55** can be provided between the radially inwardly extending first female splines **52** and the radially outwardly extending first male splines **54**. The polyamide coating **55** can be provided via applying the coating **55** to either the first female splines **52**, or preferably, for sake of ease, to the radially outwardly extending first male splines **54**, such as in a dipping process, by way of example and without limitation.

(14) The second inner surface **40** of the intermediate shaft **30** has a plurality of radially inwardly extending second female splines **56**. The second female splines **56** of the non-limiting embodiment extend from the second lower end **34** toward the second upper **32**. The second female splines **56** are shown as extending along about ⅓ the length of the intermediate shaft **30**, by way of example and without limitation. The region of the second inner surface **40** not having female spines, extending from the second female splines **56** to the second upper end **32**, has a slightly enlarged diameter D relative to the region of the second inner surface **40** having second female splines **56**, thereby allowing reduced friction between the intermediate shaft **30** the lower shaft **44** during the abnormal operating condition, as discussed further below.

(15) The second tubular wall portion **38** of intermediate shaft **30** has at least one through opening **58** adjacent the second lower end **34**. The at least one through opening **58** extends radially through the tubular wall portion **38**, and is shown as a plurality of through openings **58**. The plurality of through openings **58**, in the non-limiting embodiment, is shown including a first pair of diametrically opposite through openings **58** and a second pair of diametrically opposite through openings **58**. The through openings **58** are shown as being within the region including the second female splines **56**. The two pairs of through openings **58** are shown to be axially aligned with one another, such that each through opening **58** of one pair is axially aligned with a through opening **58** of the other pair.

(16) The second outer surface **50** of the lower shaft **44** has a plurality of radially outwardly extending second male splines **60** interdigitated with the second female splines **56** of the intermediate shaft **30**. The second male splines **60** are shown extending from the third upper end **46**

toward the third lower end **48** along a substantial majority of the length of the second outer surface **50**. The second male splines **60** and the second female splines **56**, although interdigitated with one another to prevent relative rotation between the intermediate shaft **30** and lower shaft **44** about the axis **18**, can be provided having a slight clearance fit with one another, thereby facilitating insertion and assembly of the third upper end **46** of the lower shaft **44** into the second hollow bore **42** of the intermediate shaft **30**. Then, upon inserting the third upper end **46** of the lower shaft **44** into the second hollow bore **42** of the intermediate shaft **30** to the desired position, the intermediate shaft **30** and lower shaft **44** are fixed against relative axial movement with one another, as discussed below.
(17) The second outer surface **50** of the lower shaft **44** has at least one recess **62** radially aligned with at least one through opening **58**. In the embodiment illustrated, the at least one recess includes a plurality of recesses, with each recess **62** provided as a circumferentially continuous, annular recess **58**, and shown as a pair of circumferentially continuous, annular recesses **58** spaced axially from one another along the axis **18**. Each recess **58** is radially aligned with a pair of the through openings, shown as a pair of diametrically opposite through openings **58**, such the each through opening **58** of each pair is radially aligned with one of the recesses **58** on opposite sides of the recess **58**.
(18) To fix the intermediate shaft **30** and the lower shaft **44** against relative axial movement along axis **18** with one another during the normal operating condition, a polymeric material **64** is injected through at least one through opening **58** in the intermediate shaft **30** to at least partially fill the through opening **58**, thereby forming a polymeric protrusion, referred to hereafter as protrusion **66**, extending within the through opening **58**, and through a corresponding recess **62**, thereby forming a polymeric annular body, also referred to as annulus **68**. The polymeric material **64** fixes the lower shaft **44** against movement relative to the intermediate shaft **30** along the axis **18** during the normal operating condition, whereat the strength, resiliency, and toughness of the polymeric material **64** is sufficient to withstand any axial force applied along the axis **18** during the normal operating condition.
(19) In the illustrated embodiment, the polymeric material **64** completely fills the plurality of through openings **58**, such that the protrusions **66** fill the entirety of the through openings **58**, and the associated circumferentially continuous, annular recesses **62** radially aligned with each pair of through openings **58**, such that the annulus **68** fill the entirety of the recesses **62**. Each circumferentially continuous, annular recess **62** is radially aligned not only with an associated through opening **58**, but also with a portion of the plurality of radially inwardly extending second female splines **56**, and thus, during injection of the polymeric material **64**, the polymeric material **64** flows into, conforms about and bonds with the portion of the plurality of radially inwardly extending second female splines **56**. Accordingly, the polymeric material **64**, upon solidifying, not only prevents relative axial movement between the intermediate shaft **30** and lower shaft **44**, but also facilitates preventing relative rotation between the intermediate shaft **30** and lower shaft **44**, in combination with the meshed second female splines **56** and the second male splines **60**. During the abnormal operating condition, whereat an axial force in excess of the force required to shear the polymeric material **64**, particularly across the region where the polymeric material forming the protrusions **66** transitions from the through openings **58** to the polymeric annulus **68** within the recesses **58**, is applied along the axis **18**, the protrusions **64** filling the one or plurality of through openings **58** are sheared from the annulus **68** filling one or plurality of recesses **62** during the abnormal operating condition, thereby allowing the intermediate shaft **30** and lower shaft **44** to collapse telescopically with one another along the axis **18**. It is to be recognized that with the second male splines **60** and the second female splines **56** meshing in a slight clearance fit, also referred to as loose fit, the telescoping movement is made easy and uninhibited by excessive friction.
(20) It is contemplated herein that the number of through openings **58** radially aligned with one recess **62** can be other than a pair, as desired to tune the axial force required to shear the protrusions

64 from the corresponding annulus **66**. It is further contemplated that the size (diameter) of the through openings **58** can be selected to attain the desired diameter of protrusions **64**, thereby “tuning” the force required to shear the protrusions **64** from the associated annulus **68**. Further yet, it is contemplated that a width W of the recess(es) **62** can be selected to attain the desired width of the associated annulus **68**, thereby “tuning” the bond and torsional strength of the polymeric material **64** with the second female spines **56**.

(21) In accordance with another aspect of the disclosure, a method of assembling an intermediate shaft assembly **12** includes: providing an upper shaft **20** extending along an axis **18** between a first upper end **22** and a first lower end **24**, with the first lower end **24** having a first tubular wall portion **26** with a first inner surface **28** bounding a first hollow bore **29** extending into the first lower end **24**. Further, providing an intermediate shaft **30** extending along the axis **18** between a second upper end **32** and a second lower end **34**, with the second upper end **32** having a first outer surface **36** and the second lower end **34** having a second tubular wall portion **38** with at least one port, also referred to as through opening **58**, passing radially therethrough, with the second tubular wall portion **38** having a second inner surface **40** bounding a second hollow bore **42** extending into the second lower end **34**. Further, providing a lower shaft **44** extending along the axis **18** between a third upper end **46** and a third lower end **48**, with the third upper end **46** having a second outer surface **50** with at least one recess **62** extending radially therein. Further yet, disposing the second upper end **32** in the first hollow bore **29** and releasably fixing the upper shaft **20** for controlled movement along the axis **18** relative to the intermediate shaft **30** during a normal operating condition. Further, disposing the third upper end **46** in the second hollow bore **42** with the at least one through opening **58** being radially aligned with the at least one recess **62**, and injecting polymeric material **64**, such as any desired variety of plastic, by way of example and without limitation, into at least one of the through opening(s) **58** and into the corresponding recess **62** radially aligned with the through opening(s) **58** and allowing the polymeric material to solidify within the at least one through opening **58** to form a solidified protrusion **66** and within the at least one recess **62** to form a solidified body **68** to fix the lower shaft **44** against movement along the axis **18** relative to the intermediate shaft **30** during the normal operating condition, wherein the polymeric material **64** is configured to shear under a predetermined axial load F**2**, thereby causing the protrusion(s) **66** to be sheared from the body **68** to allow the lower shaft **44** to move along the axis **18** relative to the intermediate shaft **30** during an abnormal operating condition.

(22) In accordance with another aspect of the disclosure, the method can further include providing the second inner surface **40** of the intermediate shaft **30** having a plurality of radially inwardly extending second female splines **56** and providing the the second outer surface **50** of the lower shaft **44** having a plurality of radially outwardly extending second male splines **60** interdigitated with the second female splines **56**. Further, providing the at least one recess **62** as a circumferentially continuous, annular recess **62** extending radially inwardly from the plurality of radially outwardly extending second male splines **60**. Further, radially aligning the at least one recess **62** with a portion of the plurality of radially inwardly extending second female splines **56**, and causing the polymeric material **64** to fill the circumferentially continuous, annular recess **62** to provide the body **68** as an annular body and to conform and bond with the portion of the plurality of radially inwardly extending second female splines **56**.

(23) In accordance with another aspect of the disclosure, the method can further include providing the at least one through opening as a plurality of through openings **58**, and injecting the polymeric material **64** into one of the plurality of through openings **58** and allowing the polymeric material **64** to flow out of another of the plurality of through openings **58** to indicate the circumferentially continuous, annular recess **62** being filled with the polymeric material **64**.

(24) While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations,

alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. Accordingly, the invention is not to be seen as limited by the foregoing description.

Claims

1. An intermediate shaft assembly, comprising: an upper shaft extending along an axis between a first upper end and a first lower end, said first lower end having a first tubular wall portion with a first inner surface bounding a first hollow bore extending into said first lower end; an intermediate shaft extending along said axis between a second upper end and a second lower end, said second upper end having a first outer surface and said second lower end having a second tubular wall portion with a second inner surface bounding a second hollow bore extending into said second lower end, said second upper end being disposed in said first hollow bore; and a lower shaft extending along said axis between a third upper end and a third lower end, said third upper end having a second outer surface, said third upper end being disposed in said second hollow bore, wherein said upper shaft is releasably fixed for controlled movement along said axis relative to said intermediate shaft and said lower shaft is releasably fixed against movement along said axis relative to said intermediate shaft during a normal operating condition, whereas a maximum axial force is applied along said axis during the normal operating condition, wherein said upper shaft moves along said axis relative to said intermediate shaft and said lower shaft moves along said axis relative to said intermediate shaft during an abnormal operating condition, whereat an axial force greater than said maximum axial force is applied along said axis during the abnormal operating condition.
2. The intermediate shaft assembly of claim 1, wherein said second tubular wall portion has at least one through opening and said second outer surface has at least one recess radially aligned with at least one of said at least one through opening, and further including a polymeric material at least partially filling said at least one through opening and said at least one recess, said polymeric material fixing said lower shaft against movement relative to said intermediate shaft along said axis during the normal operating condition.
3. The intermediate shaft assembly of claim 2, wherein said at least one recess is a circumferentially continuous, annular recess.
4. The intermediate shaft assembly of claim 3, wherein said polymeric material fills said circumferentially continuous, annular recess.
5. The intermediate shaft assembly of claim 4, wherein said at least one recess includes a plurality of circumferentially continuous, annular recesses spaced axially from one another along said axis.
6. The intermediate shaft assembly of claim 5, wherein said at least one through opening includes a plurality of through openings radially aligned with each one of said plurality of circumferentially continuous, annular recesses.
7. The intermediate shaft assembly of claim 6, wherein said polymeric material fills said plurality of through openings.
8. The intermediate shaft assembly of claim 2, wherein said polymeric material at least partially filling said at least one through opening is sheared from said polymeric material at least partially filling at least one recess during the abnormal operating condition.
9. The intermediate shaft assembly of claim 1, wherein said first inner surface of said upper shaft has a plurality of radially inwardly extending first female splines and said first outer surface of said intermediate shaft has a plurality of radially outwardly extending first male splines interdigitated

with said first female splines.

10. The intermediate shaft assembly of claim 9, further including a polyamide coating between said radially inwardly extending first female splines and said radially outwardly extending first male splines.

11. The intermediate shaft assembly of claim 9, wherein said second inner surface of said intermediate shaft has a plurality of radially inwardly extending second female splines and said second outer surface of said lower shaft has a plurality of radially outwardly extending second male splines interdigitated with said second female splines.

12. The intermediate shaft assembly of claim 11, wherein said second tubular wall portion of said intermediate shaft has at least one through opening and said second outer surface of said lower shaft has at least one recess radially aligned with at least one of said at least one through opening, and further including a polymeric material at least partially filling said at least one through opening and said at least one recess, said polymeric material fixing said lower shaft against movement relative to said intermediate shaft along said axis during the normal operating condition.

13. The intermediate shaft assembly of claim 12, wherein said at least one recess is a circumferentially continuous, annular recess extending radially inwardly from said plurality of radially outwardly extending second male splines, wherein said polymeric material fills said circumferentially continuous, annular recess.

14. The intermediate shaft assembly of claim 13, wherein said circumferentially continuous, annular recess is radially aligned with a portion of said plurality of radially inwardly extending second female splines, said polymeric material conforming and bonding with said portion of said plurality of radially inwardly extending second female splines.

15. The intermediate shaft assembly of claim 1, wherein said first hollow bore of said upper shaft extends from said first upper end to said first lower end, and wherein said second hollow bore of said intermediate shaft extends from said second upper end to said second lower end.

16. The intermediate shaft assembly of claim 15, wherein said second upper end of said intermediate shaft is between said first upper end and said first lower end of said upper shaft during the normal operating condition, and wherein said first upper end of said upper shaft is between said second upper end and said second lower end of said intermediate shaft during the abnormal operating condition.

17. The intermediate shaft assembly of claim 16, wherein said second lower end of said intermediate shaft is between said first lower end of said upper shaft and said third lower end of said lower shaft during the normal operating condition, and wherein said first lower end of said upper shaft is between said second lower end of said intermediate shaft and said third lower end of said lower shaft during the abnormal operating condition.

18. A method of assembling an intermediate shaft assembly, the method comprising: providing an upper shaft extending along an axis between a first upper end and a first lower end, said first lower end having a first tubular wall portion with a first inner surface bounding a first hollow bore extending into said first lower end; providing an intermediate shaft extending along said axis between a second upper end and a second lower end, said second upper end having a first outer surface and said second lower end having a second tubular wall portion with at least one through opening passing radially therethrough, said second tubular wall portion having a second inner surface bounding a second hollow bore extending into said second lower end; providing a lower shaft extending along said axis between a third upper end and a third lower end, said third upper end having a second outer surface with at least one recess extending radially therein; disposing said second upper end in said first hollow bore and releasably fixing said upper shaft for controlled movement along said axis relative to said intermediate shaft during a normal operating condition; disposing said third upper end in said second hollow bore with said at least one through opening being radially aligned with said at least one recess; and injecting polymeric material into at least one of said at least one through opening and into said at least one recess and allowing said

polymeric material to solidify within said at least one through opening and within said at least one recess to fix said lower shaft against movement along said axis relative to said intermediate shaft during the normal operating condition, wherein said polymeric material is configured to shear under a predetermined axial load to allow said lower shaft to move along said axis relative to said intermediate shaft during an abnormal operating condition.

19. The method of claim 18, further including: providing said second inner surface of said intermediate shaft having a plurality of radially inwardly extending second female splines and providing said second outer surface of said lower shaft having a plurality of radially outwardly extending second male splines interdigitated with said second female splines; providing said at least one recess as a circumferentially continuous, annular recess extending radially inwardly from said plurality of radially outwardly extending second male splines; radially aligning said at least one recess with a portion of said plurality of radially inwardly extending second female splines; and causing said polymeric material to fill said circumferentially continuous, annular recess and to conform and bond with said portion of said plurality of radially inwardly extending second female splines.

20. The method of claim 19, further including providing said at least one through opening as a plurality of through openings, and injecting said polymeric material into one of said plurality of through openings and allowing said polymeric material to flow out of another of said plurality of through openings to indicate said circumferentially continuous, annular recess being filled with said polymeric material.