

A FLEXIBLE SHAFT COUPLING APPARATUS FOR TRANSMISSION OF TORQUEFIELD OF THE INVENTION

5

The present invention relates to a flexible shaft coupling for transmission of torque which is installed between a driving shaft and a driven shaft of industrial machinery and automobiles.

BACKGROUND OF THE INVENTION

10

Mechanical power transmission is the transfer of power and rotation from one place to another using mechanical elements. Specifically, mechanical power transmission is the transfer of mechanical work from where it is generated to where it is used. Nearly all machines have some kind of power and motion transmission from an input source generating said power and motion.

15 The input source is usually a motor or an internal combustion engine which typically provides rotary driving torque via an input shaft-coupling, or in other words a drive shaft coupling combination.

Drive shaft couplings require a certain degree of flexibility to handle the axial displacement that occurs between coupling shafts during rotation, especially at higher speeds/torque when driven under practical drive conditions. In this regard, many types of coupling are known in the art and these include link-type couplings and Oldham's coupling. However, these couplings have rigid components and therefore provide limited damping under high torsional loads. These couplings, as a result, are associated with high torsional disturbances during driving of a driven load leading to undesirable vibration, noise, and loss of transmission efficiency.

Recently, elastomeric flexible couplings have been introduced to provide improved damping properties and absorption of torsional inputs. Some elastomeric couplings have internal fibres to assist in absorbing the torsional load during rotational operation. These couplings are placed between metal discs affixed to the end of two adjoining coupling shafts. This arrangement however, suffers from the limitation of offering limited flexibility for angular misalignment between the intersecting shafts. Furthermore, torsional loads are not well distributed within the couplings due to bending of internal fibres that occur during rotation.

To date, several attempts have been made to address the limitations of conventional drive shaft couplings, which include among others, limited angular flexibility and inability to compensate for reactionary forces that result from torque transmission.

5

These attempts are demonstrated by the following prior art references.

United States Patent No. 4,790,794 provides a flexible shaft coupling for transmission of high torque loads comprising drive side and driven side connecting elements arranged in pairs alternately and equidistantly in a circumferential orientation, endless belts of fiber cord bundles wrapping around and interlinking pairs of adjacent drive side and driven side connecting elements, and an elastomeric material embedding therein the foregoing members. Between the connecting elements and the belts, there are mounted bobbin-like collars each having both terminal flanges defining a hollow of U-shaped cross-section between them, and the belts are received and held in the hollows. By the construction, disorder or relaxing in the cords is not caused and loads are dispersed uniformly on the cords with the result that high torque transmission efficiency is attained.

United States Patent Application Publication No. US 2005/0085304 A1 provides an elastomeric coupling for a rotating shaft including a driving yoke, a driven yoke, and a substantially circular elastomeric body having a circumferential face and first and second sets of bushings within the elastomeric body. The bushings have threaded openings exposed at the circumferential face. A plurality of fasteners secures the driving yoke to the first set of bushings and secures the driven yoke to the second set of bushings. A plurality of tensile members is located within the elastomeric body, with tensile members connecting the first set of bushings to the second set of bushings.

25

Taking into consideration the prior art references, United States Patent No. 4,790,794, merely provides a shaft coupling that is directed at improving torque transmission efficiency by improving the integrity of the coupling between a driven side shaft and driving side shaft, without addressing the problem of providing a torsion stiff shaft coupling that is able to compensate for a torsion disturbance, thus reducing vibration and noise while providing an improved torque transmission efficiency. United States Patent Application Publication No. US 2005/0085304 A1 on the other hand, despite providing a torsion stiff spacer element to enhance torque transmission efficiency and thus minimize undesirable vibrations, only provides limited angular flexibility.

30

It thus appears that to date, none of the prior art shaft couplings allow transmission of torque from the driving shaft to the driven shaft while satisfactorily mitigating the incidence of reactionary forces that result from the transmission of torque despite a large angular displacement between the driven shaft and the driving shaft to thus provide smooth torque transmission.

In view of the above, it would be desirable if an apparatus or device for coupling a driving shaft to a driven shaft that overcomes the limitation of prior art shaft couplings be conceived.

10

SUMMARY OF THE INVENTION

The following presents a simplified summary of the invention in order to provide a basic understanding of some aspects of the invention. This summary is not an extensive overview of the invention. It is, not intended to identify key/critical elements of the invention. Its sole purpose is to present some concepts of the invention in a simplified form as a prelude to the more detailed description that is, presented later.

The present invention provides a flexible shaft coupling apparatus for transmitting torque from a driving shaft driven by a prime mover such as a motor or an internal combustion engine, to a driven shaft coupled to a mechanical load. The apparatus comprises a spacer element circumscribed and mechanically coupled at symmetrically opposing ends with a pair of articulated joints, a first articulated joint and a second articulated joint. The spacer element is substantially deformable in any direction transverse to its axis of rotation despite being torsion stiff and is thus dispensed with bending flexibility when subject to reactionary forces that result from torque transmission. The spacer element is configured to transmit torque from the first articulated joint mechanically coupled to a driving shaft, to the second articulated joint mechanically coupled to a driven shaft via the spacer element. Exemplarily, the first and second articulated joints that form the pair of articulated joints circumscribing the spacer element at symmetrically opposing ends are universal joints.

In accordance with embodiments of the present invention, the spacer element in addition to being substantially deformable in any direction transverse to its axis of rotation, is also an axially deformable element and is thus axially flexible.

- 5 In a first embodiment of the present invention, the spacer element comprises a torsional stiff substantially cylindrical member that is substantially axially deformable and substantially deformable in any direction transverse to its axis of rotation thus exhibiting both axial flexibility and bending flexibility. Preferably, the torsional stiff substantially cylindrical member is mechanically coupled at symmetrically opposing longitudinal ends to the respective first and
10 second articulated joints via a disc pack assembly comprising a plurality of disc-shaped metal membranes.

- In a second embodiment of the present invention, the spacer element comprises a pair substantially hollow cylindrical half members that are mechanically coupled to each other to form a hollow
15 cylindrical spacer element that is both substantially axially deformable and substantially deformable in any direction transverse to its axis of rotation. This spacer element in this embodiment thus exhibits both axial flexibility and bending flexibility.

- In a third embodiment of the present invention, the spacer element comprises a central cylindrical
20 disc-shaped member having symmetrically opposing and outwardly projecting surfaces that are each disposed with a pair of outwardly projecting substantially longitudinally rigid tubular members that are respectively mechanically coupled to the first and second articulated joints. In this embodiment, the spacer element as a whole is substantially deformable in any direction transverse to its axis of rotation and thus exhibits bending flexibility while not being substantially
25 axially deformable because any reactionary force due to torque transmission which tends to cause axial deformation is inherently converted to a reactionary force which causes deformation in a direction transverse to the axis of rotation of the spacer element.

- It is an advantage of the present invention to provide a flexible shaft coupling apparatus that is
30 capable of coupling a driving shaft to a driven shaft despite the angular displacement between the driven shaft and driving shaft being greater than 3°.

It is an advantage of the present invention to provide a flexible shaft coupling apparatus that is capable of coupling a driving shaft to a driven shaft despite effectively mitigating the effects of reactionary forces that result from torque transmission to thus allow smooth torque transmission.

- 5 It is an advantage of the present invention to provide a flexible shaft coupling apparatus that is capable of coupling a driving shaft to a driven shaft to thus provide smooth torque transmission despite large angular misalignment between the driving shaft and the driven shaft.

- 10 It is an advantage of the present invention to provide a flexible shaft coupling apparatus that exhibits reduced vibration and noise when in operation.

BRIEF DESCRIPTION OF THE DRAWINGS

- 15 The above and other objects, features and other advantages of the present invention will be, more clearly understood, from the detailed description taken in conjunction with the accompanying drawings, in which:

- 20 Figure 1 illustrates a perspective view of a flexible shaft coupling apparatus for transmitting torque from a driving shaft to a driven shaft, according to a first embodiment of the present invention;

Figure 2 illustrates a perspective view of a flexible shaft coupling apparatus for transmitting torque from a driving shaft to a driven shaft, according to a second embodiment of the present invention;

- 25 Figure 3 illustrates a perspective view of a flexible shaft coupling apparatus for transmitting torque from a driving shaft to a driven shaft, according to a third embodiment of the present invention; and

- 30 Figure 4 illustrates an exploded view of an example disc pack assembly that may be utilized in an embodiment of the flexible shaft coupling apparatus for transmitting torque from a driving shaft to a driven shaft of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The detailed description set forth below in connection with the appended drawings is intended as a description of an exemplary embodiment and is not intended to represent the only form in which
5 the embodiment may be constructed and/or utilized. The description sets forth the functions and the sequence for constructing the exemplary embodiment. However, it is to be understood, that the same or equivalent functions and sequences may be accomplished by different embodiments that are also intended to be encompassed within the scope of this disclosure.

10 With reference to Figures 1 to 4, embodiments of the present invention provide a flexible shaft coupling apparatus **100** for transmitting torque from a driving shaft driven by a prime mover, such as a motor or an internal combustion engine, to a driven shaft coupled to a mechanical load. The apparatus **100** comprises a spacer element **30** circumscribed and mechanically coupled at
15 symmetrically opposing ends with a pair of articulated joints **10a**, **10b**, a first articulated joint **10a**, and a second articulated joint **10b**. The apparatus **100** for transmitting torque as provided in embodiments of the present invention, allow for the transmission of torque from said driving shaft to said driven shaft, while compensating for torque disturbances which arise due to the transmission of torque from the first articulated joint **10a** to the spacer element **30** and subsequently from the spacer element **30** to the second articulated joint **10b** and finally from the second
20 articulated joint **10b** to a driven shaft.

The apparatus **100** as provided in embodiments of the present invention, compensates for the effects of reactionary forces that result from torque transmission by providing a spacer element **30** that is dispensed with the property of being substantially deformable in any direction transverse to
25 its axis of rotation and thus exhibits bending flexibility despite being torsion stiff. Moreover, in a preferred embodiment of the apparatus **100**, the spacer element **30** is dispensed with both the property of being substantially deformable in any direction transverse to its axis of rotation and substantially axially deformable, thus exhibiting both bending flexibility and axial flexibility. The property of the spacer element **30** of the apparatus **100** exhibiting bending flexibility or a
30 combination of bending and axial flexibility despite being torsion stiff, allows for reactionary forces that occur as a result of torque transmission by the articulated joints **10a**, **10b** to be compensated for due to the bending and axial flexibility of the spacer element **30**. It would be readily understood by one of ordinary skill in the art, that the term “flexibility” as mentioned herein

refers to the ability of a given material to be deformed without breaking. Thus, the apparatus **100** as provided in embodiments of the present invention, compensates for reactionary forces that arise due to torque transmission by manifesting the reactionary forces as forces that cause deformation in a direction transverse to the axis of rotation of the spacer element **30** or a combination of
5 deformation in a direction transverse to the axis of rotation of the spacer element **30** and axial deformation of the spacer element **30** (i.e. cause axial deformation and bending of the spacer element **30**).

In embodiments of the apparatus **100** of the present invention as shown in Figures 1 to 3, the first
10 and second articulated joints **10a**, **10b** are universal joints **10a**, **10b** that cooperate with one another to mechanically couple a driving shaft that is both axially and radially displaced from a driven shaft in order to realize torque transmission between the driving shaft and the driven shaft via the spacer element **30**. It would be readily understood by one of ordinary skill in the art, universal joints are joints configured to connect rigid shafts whose axes are inclined to each other despite
15 being axially and radially displaced. These joints are configured to transmit rotary motion and comprise a pair of hinges oriented at 90° to each other and interlinked by a cross shaft.

With reference to Figure 1, in a first embodiment of the apparatus **100** of the present invention, the spacer element **30** is a substantially cylindrical member fabricated from a composite material
20 that allows it to be substantially axially deformable and substantially deformable in any direction transverse to its axis of rotation thus exhibiting both axial flexibility and bending flexibility. Preferably, in said first embodiment of the apparatus **100**, the torsional stiff substantially cylindrical member forming the spacer element **30** is mechanically coupled at symmetrically opposing longitudinal ends to the respective first and second articulated joints **10a**, **10b** by a disc pack assembly **20a**, **20b** comprising a plurality of disc-shaped metal membranes.
25

Referring to Figures 1 and 4, by way of introduction, disc pack assemblies **20a**, **20b** in general are utilized to compensate for misalignment between rotating shafts to a limited degree, apart from reducing reactionary forces on equipment coupled by the disc pack assembly **20a**, **20b** and
30 providing a degree of damping to reactionary forces that result from torque transmission. A typical disc pack assembly **20a**, **20b** comprises one or more substantially disc-shaped metal membranes **20v**. Each disc-shaped metal membrane **20v** includes a plurality of radially distributed and equidistantly spaced perforations **20vi**. When the disc-shaped metal membranes **20v** of the disc

pack assembly **20a, 20b** are stacked together, the plurality of perforations **20vi** of each disc-shaped metal membrane **20v** align with perforations **20vi** of the other disc-shaped metal membranes **20v** of the disc pack assembly **20a, 20b** to form a substantially cylindrical channel configured to receive and house mounting bushings **20ii** which in turn are configured hold in place the stack of disc-shaped metal membranes **20v** and to receive threaded bolts **20iii** which are securable to complementarily threaded nuts **20iv** which allow the disc pack assembly **20a, 20b** to be effectively coupled to a pair of misaligned shafts. With reference to the first embodiment of the apparatus **100** shown in Figure 1, the substantially cylindrical spacer element **30** is disposed with an adaptation at symmetrically opposing longitudinal ends, to allow the disc pack assemblies **20a, 20b** to be secured thereto. Preferably, this adaptation takes the form of a flange **30a, 30b** integrally formed with said symmetrically opposing longitudinal ends of the spacer element **30** and disposed with a plurality of circumferentially distributed and equidistantly spaced perforations that are aligned with the mounting bushings **20ii** of the disc pack assembly **20a, 20b**, thus allowing a disc pack assembly **20a, 20b** to be mechanically and fixedly attached to the substantially cylindrical spacer element **30** by way of bolts **20iii** and nuts **20iv**. Moreover, referring to Figure 1 yet again, the pair of universal joints **10a, 10b** of the apparatus **100** are disposed with ends configured to be mechanically coupled to the substantially cylindrical spacer element **30** via the disc pack assembly **20a, 20b**. Exemplarily, these ends take the form of a flange member **10i** having a plurality of circumferentially distributed and equidistantly spaced apart perforations that are also aligned with the mounting bushings **20v** of the disc pack assembly **20a, 20b**, thus allowing the disc pack assemblies **20a, 20b** to be respectively mechanically and fixedly attached to the universal joints **10a, 10b**.

Referring to Figure 1, in an exemplary embodiment, each disc-shaped metal membrane **20v** of the disc pack assembly **20a, 20b** is selected from a scalloped or non-scalloped disc-shaped metal membrane **20v**. Combination of the disc pack assemblies **20a, 20b** and the spacer element **30** exhibiting axial and bending flexibility provide a superior compensation of reactionary forces that arise due to torque transmission as compared to prior art flexible shaft couplings.

With reference to Figure 2, in a second embodiment of the apparatus **100** of the present invention, the spacer element **30** comprises a pair of substantially cylindrical hollow half members **30a, 30b** that are adaptably connected to each other to form a hollow cylindrical spacer element **30** that exhibits both axial flexibility and bending flexibility. The pair of substantially cylindrical hollow

half members **30a**, **30b** each comprise a first end **30i** disposed with a substantially circular end face and a second end **30ii** disposed with an opening to a substantially cylindrical cavity. Exemplarily, the pair of substantially cylindrical hollow half members **30a**, **30b** are each respectively disposed at an outer periphery of a circumferential edge of the second end **30ii**
5 defining the opening to the substantially cylindrical cavity, with complementarily configured coupling members that are configured to cooperate with one another to enable each of the pair of hollow cylindrical members **30a**, **30b** to be physically fixedly attached to one another at respective second ends **30ii** to form a hollow substantially cylindrical spacer element **30** that exhibits both axial and bending flexibility. The axial flexibility and bending flexibility of the spacer element **30**
10 of the apparatus **100** in this embodiment arises from the malleability and ductility of the material forming the pair of substantially hollow cylindrical half members **30a**, **30b** of the substantially hollow cylindrical spacer element **30**.

With reference to Figure 3, in a third embodiment of the apparatus **100** of the present invention,
15 the spacer element **30** comprises a central cylindrical disc-shaped member **30a** having symmetrically opposing and outwardly projecting surfaces **30ai**, **30aii** that are each disposed with a pair symmetrically spaced apart outwardly projecting substantially longitudinally rigid tubular members **30b**, **30c**, **30d**, **30e**. Specifically, a first pair of symmetrically spaced apart substantially longitudinally rigid tubular members **30b**, **30c** project outwardly from surface **30ai** of the
20 cylindrical disc-shaped member **30a** and a second pair of symmetrically spaced apart longitudinally rigid tubular members **30d**, **30e** project outwardly from surface **30aii** of the aforementioned cylindrical disc-shaped member **30a**. Aforementioned first and second pairs of outwardly projecting symmetrically spaced apart longitudinally rigid tubular members **30b**, **30c**, **30d**, **30e** are respectively fixedly attached to the first and second universal joints **10a**, **10b** at
25 outwardly projecting ends thereof. The first and second universal joints **10a**, **10b** are exemplarily configured to receive, house and fixedly attach to a portion of the outwardly projecting ends of the respective first and second pairs of outwardly projecting symmetrically spaced apart longitudinally rigid tubular members **30b**, **30c**, **30d**, **30e**. Preferably, the first pair of outwardly projecting symmetrically spaced apart longitudinally rigid tubular members **30b**, **30c** are oriented transverse
30 to the second pair of outwardly projecting symmetrically spaced apart longitudinally rigid tubular members **30d**, **30e**. In aforementioned third embodiment of the apparatus **100** of the present invention, the configuration of the spacer element **30** comprising the central cylindrical disc-shaped member **30a** and the first and second pairs of substantially longitudinally rigid tubular

members **30b**, **30c**, **30d**, **30e** render a property of bending flexibility, but no substantial axial flexibility. In other words, the spacer element **30** of the embodiment of the apparatus **100** shown in Figure 3 is substantially deformable in any direction transverse to its axis of rotation but not substantially axially deformable.

5

Alternative embodiments will become apparent to those skilled in the art to which the present invention pertains without departing from its scope. Accordingly, the scope of the present invention is defined by the appended claims rather than the foregoing description.

10

CLAIMS

1. A flexible shaft coupling apparatus (100) for transmitting torque from a driving shaft driven by a prime mover to a driven shaft coupled to a mechanical load, characterized in that the
5 apparatus (100) comprises:
a spacer element (30) circumscribed and mechanically coupled at symmetrically opposing ends respectively with a first articulated joint (10a) and a second articulated joint (10b),
wherein the spacer element (30) is substantially deformable in any direction transverse to its axis of rotation despite being torsion stiff and is thus dispensed with bending flexibility when
10 subject to reactionary forces that result from torque transmission, and
wherein the spacer element (30) is configured to transmit torque from the first articulated joint (10a) mechanically coupled to a driving shaft to the second articulated joint (10b) mechanically coupled to a driven shaft via the spacer element (30).
- 15
2. The flexible shaft coupling apparatus (100) according to claim 1, wherein the spacer element (30) is substantially axially deformable in addition to being substantially deformable in any direction transverse to its axis of rotation.
- 20
3. The flexible shaft coupling apparatus (100) according to claim 1, wherein the first articulated joint (10a) and second articulated joint (10b) are universal joints.
- 25
4. The flexible shaft coupling apparatus (100) according to claim 1, wherein the spacer element (30) is a substantially cylindrical member fabricated from a light-weight material.
5. The flexible shaft coupling apparatus (100) according to claim 4, wherein the light-weight
30 material is a carbon-fiber composite material.
6. The flexible shaft coupling apparatus (100) according to claim 4, wherein the spacer element (30) is mechanically coupled at symmetrically opposing longitudinal ends to the

respective first and second articulated joints (10a, 10b) via a disc pack assembly (20a, 20b) comprising a plurality of disc-shaped metal membranes (20v).

5 7. The flexible shaft coupling apparatus (100) according to claim 1, wherein the spacer element (30) comprises a pair substantially hollow cylindrical half members (30a, 30b) that are mechanically coupled to each other to form a hollow cylindrical spacer element (30).

10 8. The flexible shaft coupling apparatus (100) according to claim 1, wherein the spacer element (30) comprises a central cylindrical disc-shaped member (30a) having symmetrically opposing and outwardly projecting surfaces (30ai, 30aia) that are each disposed with a pair of outwardly projecting substantially longitudinally rigid tubular members (30b, 30c, 30d, 30e) that are respectively mechanically coupled to the first and second articulated joints (10a, 10b).

15

9. The flexible shaft coupling apparatus (100) according to claim 1, wherein the prime mover includes a motor and an internal combustion engine.

20