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BREAK AWAY SPLINE MISALIGNMENT COUPLING

BACKGROUND OF THE INVENTION

It is common for a torsion drive to be employed between an engine and a drive accessory. For example, in automobiles, a belt drive is often used to transfer power
5 from the engine to various accessories, such as a compressor, alternator, generator and numerous pumps. Should any of these accessories experience a catastrophic failure, such as a seized bearing, the accessory will cease functioning and the belt drive will continue to function properly. Although the belt will slip past the non-functioning accessory, possibly causing damage to the belt itself, it is extremely unlikely that
10 damage to other accessories or the engine will occur as a result of the failure of the accessory.

In small aircraft, however, a belt drive is not used to power accessories from an engine. Rather, accessories are driven directly from gears disposed in an accessory case typically located at the rear of the engine. In this design, should a catastrophic failure
15 occur in an accessory, such as a seized bearing as described above or a broken rotor shaft, excessive torques may be experienced throughout the system, including other accessories or even the engine itself. Because all components, including the engine and its accessories, are linked mechanically via the system of gears and shafts, a failure of any one accessory that causes its rotating components to stop, may cause the entire
20 system of the engine and its accessories to seize up. Such extreme torques also can cause damage to those components as well as the gears used to drive them. For example, the seizing of one component mechanically linked to another also may cause that other component to seize or may cause teeth to break off gears. Thus, although mechanical drives are less likely to fail because of a worn belt, they lack the failsafes

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that belts provide in preventing damage to components in the event of a catastrophic failure of a component of the system.

SUMMARY OF THE INVENTION

A torque-limiting coupling may provide a torsion drive between an engine and a driven accessory. If the accessory should experience a catastrophic failure, such as a locked bearing or broken rotor shaft, a torsion-limited spline breaks away from the coupling. This guarantees that the internal engine gearing used to drive the accessory is neither compromised nor interferes with other essential moving parts inside the engine. Further, misalignment compensation provided by a lobe end limits the side load and wear that occurs when coupling two precision shafts with little clearance on the bearings. With a misalignment coupling, the respective shafts can be mounted slightly out of parallel with no negative effects.

More particularly, a torque-limiting coupler comprises a first end configured to mate to a first receiver coaxially located in a first component configured to rotate, and a second end configured to mate to a second receiver coaxially located in a second component configured to rotate. A neck region between the first and second ends is configured to experience higher shear stresses than the first and second ends when torque is applied.

The neck region provides a highly predictable clean break with no failure or stripping of drive components. A portion of the neck region may have a smaller cross-sectional area than either the first end or the second end. The smaller cross-sectional area may be manufactured, for example, by creating a bore through the neck region or by reducing the outer diameter of the neck region.

The first end may include a spline fitting, which may conform to the AND20000 mounting convention. Further, the second end may include at least one cam lobe or, alternatively, two opposing cams. A band of material having a softer durometer than the material of the second end, such as a rubber ring (*e.g.*, Viton®), may surround at least a portion of the second end.

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BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing will be apparent from the following more particular description of example embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views.

5 The drawings are not necessarily to scale, emphasis instead being placed upon illustrating embodiments of the present invention.

FIG. 1 is a perspective diagram of a torque-limiting coupling in a disassembled state according to an example embodiment of the present invention.

10 FIG. 2A is a perspective diagram of the example embodiment break away spline coupler of FIG. 1.

FIG. 2B is a lateral diagram of the example embodiment break away spline coupler of FIG. 2A.

FIG. 2C is an axial diagram of the example embodiment break away spline coupler of FIG. 2A from a lobe end.

15 FIG. 2D is an axial diagram of the example embodiment break away spline coupler of FIG. 2A from a spline end.

FIG. 2E is a cross-sectional diagram of the example embodiment break away spline coupler of FIG. 2D taken along line A.

20 FIG. 2F is a lateral diagram of the example embodiment break away spline coupler of FIG. 2A in blank form prior to shaping of the splines.

FIG. 3A is a perspective diagram of the example embodiment break away spline receiver of FIG. 1.

FIG. 3B is a lateral diagram of the example embodiment break away spline receiver of FIG. 3A.

25 FIG. 3C is a lateral diagram of the example embodiment break away spline receiver of FIG. 3A rotated ninety degrees axially from its orientation as shown in FIG. 3B.

FIG. 3D is an axial diagram of the example embodiment break away spline coupler of FIG. 3A from a receiver bore end.

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FIG. 3E is a cross-sectional diagram of the example embodiment break away spline coupler of FIG. 3D taken along line A.

FIG. 4A is a perspective diagram of the example embodiment torque-limiting coupling of FIG. 1 in an assembled state.

5 FIG. 4B is a lateral diagram of the assembled example embodiment torque-limiting coupling of FIG. 4A.

FIG. 4C is an axial diagram of the assembled example embodiment torque-limiting coupling of FIG. 4A from the break away spline coupler 105 end.

10 FIG. 4D is a cross sectional diagram of the assembled example embodiment torque-limiting coupling of FIG. 4C taken along line A.

DETAILED DESCRIPTION OF THE INVENTION

A description of example embodiments of the invention follows.

FIG. 1 is a perspective diagram of a torque-limiting coupling 100 in a disassembled state, comprising a break away spline coupler 105 and a break away spline receiver 150. The break away spline coupler 105 comprises a spline end 110 and a lobe end 130. The break away spline receiver 150 comprises a receiver end 152 and a shaft end 175. In its assembled state, discussed below with reference to FIGS. 4A-4D, the assembled coupler 100 further includes an o-ring 180 and a retaining ring 190.

20 FIGS. 2A-2F illustrate several views of the break away spline coupler 105 of FIG. 1.

FIG. 2A is a perspective diagram of the break away spline coupler 105 of FIG. 1. The break away spline coupler 105 comprises a spline end 110 and a lobe end 130. The spline end 110 includes a plurality of longitudinally extending circumferentially spaced splines 115 and is configured to be mated coaxially to a transmission output of a torque generating device, such as an engine (not shown). The spline end 110 further includes a bore 120 for tuning the break away spline coupler 105 to break at a predefined torque, also discussed below with reference to FIGS. 4A-4D. The lobe end 130 of the break away spline coupler 105 includes a lobe 135, with an o-ring slot 140 included thereon, and is configured to couple the break away spline coupler 105

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coaxially to the break away spline receiver (*e.g.*, break away spline receiver 150 of FIG. 1).

FIG. 2B is a lateral (or side view) diagram of the break away spline coupler 105 of FIG. 2A. The bore 120 may be employed in conjunction with a neck region 125 of the break away spline coupler 105, the diameter of which also may be tuned to set the predefined breaking torque of the coupler 105. Further, the o-ring slot 140, located between the cam lobes 135, may accept an o-ring (*e.g.*, o-ring 180 of FIG. 1) during assembly of the torque-limiting coupler 100.

FIG. 2C is an axial diagram of the break away spline coupler 105 of FIG. 2A from the lobe end 130. As illustrated, the lobe 135 is defined, in part, by a major lobe diameter 137 and a minor lobe diameter 138. FIG. 2D is an axial diagram of the example embodiment break away spline coupler 105 of FIG. 2A from the spline end 110. As illustrated, the spline end 110 of the break away spline coupler 105 includes the plurality of splines 115 and the axial bore 120 for tuning the break away spline coupler 105 to break at a predefined torque.

FIG. 2E is a cross-sectional diagram of the break away spline coupler 105 of FIG. 2D taken along line A. As can be seen, the bore 120 may, for example, be drilled from the spline end 110 to a particular depth toward, into or even across the neck region 125 of the break away spline coupler 105. Further, the outer diameter of the neck region 125 may be adjusted. The depth of the bore 120 in combination with the outer diameter of the neck region may be used to change the cross-sectional area of the neck region 125, thereby allowing the breaking torque of the break away spline coupler 105 to be adjusted.

FIG. 2F is a lateral diagram of the break away spline coupler 105 of FIG. 2B in blank form prior to shaping of the splines 115 (not shown). The splines may be shaped on the spline end 130 of the break away spline coupler 105, for example, by a machining process. Further, the depth of the bore 120 and the outer diameter of the neck region 125 may adjusted as well.

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FIGS. 3A-3E illustrate several views of the break away spline receiver 150 of FIG. 1.

FIG. 3A is a perspective diagram of the break away spline receiver 150 of FIG. 1. The break away spline receiver 150 comprises a receiver end 152 and a shaft end 175. The receiver end 152 includes a receiver bore 155 for receiving a lobe end of a break away spline coupler (*e.g.*, the lobe end 130 of the break away spline coupler 105 of FIGS. 2A-2F) and gaps 160 for accommodating a major lobe diameter of a lobe end of a break away spline coupler (*e.g.*, the major lobe diameter 137 of the lobe end 135 of the break away spline coupler 105 of FIG. 2C). The shaft end 175 of the break away spline receiver 150 is configured to transfer power to other coaxial components (not shown).

FIG. 3B is a lateral diagram of the break away spline receiver 150 of FIG. 3A. As illustrated, the receiver end 152 includes a retaining ring installation slot 165 and a retaining ring installation lip 170 which, in combination, secure a retaining ring (*e.g.*, the retaining ring 190 of FIG. 1) for assembling the torque-limiting coupling of FIG. 1.

FIG. 3C is a lateral diagram of the break away spline receiver 150 of FIG. 3A rotated ninety degrees axially from its orientation as shown in FIG. 3B. As can be seen, the retaining ring installation slot 165 and the retaining ring installation lip 170 are interrupted circumferentially by the gaps 160 for accommodating the major lobe diameter 137 of the lobe end 135 of the break away spline coupler 105 of FIG. 2C. These features can also be seen in FIG. 3D, which is an axial diagram of the example embodiment break away spline coupler 150 of FIG. 3A from a receiver bore end 152, and FIG. 3E, which is a cross-sectional diagram of the example embodiment break away spline coupler 150 of FIG. 3D taken along line A. Note that the axial orientation of the break away spline receiver 150 in the cross sectional diagram of FIG. 3E corresponds to that of the break away spline receiver 150 as illustrated in FIG. 3C.

FIGS. 4A-4D illustrate several views of the assembled torque-limiting coupling 100 of FIG. 1.

FIGS. 4A-4B are perspective and lateral (or side view) diagrams, respectively, of the assembled torque-limiting coupling 100 of FIG. 1. Referring to both FIGS. 1 and

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4A, the o-ring 180 may be inserted into the o-ring slot 140 prior to inserting the lobe end 130 of the break away spline coupler 105 into the receiver bore 155 of the break away spline receiver 150. After insertion of the lobe end 130 of the break away spline coupler 105 into the receiver bore 155 of the break away spline receiver 150, the
5 retaining ring 190 may be installed, via its opening 195 into the retaining ring installation slot 160 of the break away spline receiver 150, thereby securing the break away spline coupler 105 to the break away spline receiver 150 to form the assembled torque-limiting coupling 100. As shown in FIG. 4B, the opening 195 in the retaining ring 190 is visible.

10 FIG. 4C is an axial diagram of the torque-limiting coupling 100 of FIG. 4A from the break away spline coupler 105 end. A cross-sectional diagram of the torque-limiting coupling 100 of FIG. 4C taken along line A is provided in FIG. 4D. As can be seen, the retaining ring 190 secures the break away spline coupler 105 to the break away spline receiver 150 by inhibiting lateral movement of the lobe end 130 of the break
15 away spline coupler 105 from the receiver bore 155 of the break away spline receiver 150 by contacting both the lip 170 of the break away spline receiver 150 and a surface 132 of the lobe 135. Further, the o-ring 180 is installed in the o-ring slot 140. The o-ring 180, which may have a softer durometer than the material from which the break away spline coupler 105 is manufactured, may eliminate rattle produced by the
20 break away spline coupler 105 as installed with the break away spline receiver 150, thereby reducing vibration and wear in the coupling 100. Such an o-ring 180 may be a high temperature o-ring and may be made of Viton®.

The break away spline coupler 105 may be configured during manufacture to break at the neck region 125 at a particular torque limit. The geometry of the neck
25 region 125 (*i.e.*, fracture zone) may be designed for adjusting the torque limit to exact requirements by reducing the cross-sectional area of the neck region 125, thus causing higher shear stresses to be experienced. The cross sectional area of the neck 125 may be reduced, at least, by: (1) adjusting the depth of the bore 120 (*e.g.*, shallower or deeper into the break away spline coupler 105); (2) changing the outer diameter of the
30 neck region 125; and (3) a combination of both. The break at the neck region 125 is

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therefore highly predictable and results in a clean break with no failure or stripping of the drive feature. This eliminates, or at least reduces, the possibility that a failure of an accessory can cause the failure of engine components by introducing fragments into the gear case.

5 Thus, the assembled torque-limiting coupling 100 may provide a torsion drive between an engine (*e.g.*, an aircraft engine) and a driven accessory (*e.g.*, a generator). If the accessory should experience a catastrophic failure, such as a locked bearing or a broken rotor shaft, a torsion limit is exceeded and the spline 105 breaks away from the coupling 100. This guarantees that the internal engine gearing used to drive the
10 accessory is not compromised and interfering with essential moving parts inside the engine.

 Further, misalignment compensation provided by the lobe end 130, including the cam lobe 135, the o-ring 180, and the receiver bore 155, limits the side load and wear that occurs when coupling two precision shafts with little clearance on the bearings.

15 With a misalignment coupling 100, the mount can be slightly out of parallel with no negative effects

 The torque-limiting coupling 100 may conform to the AND20000 convention for providing a drive and mounting configuration of the engine and its accessories. As understood by one of ordinary skill in the art, the male spline 115 on the coupling 100 is
20 installed in the AND20000 female spline (not shown). It is common that extra clearance is provided such that the male spline 115 fits loosely, thereby accommodating easy installation and allowing for thermal expansion.

 The components of the torque-limiting coupling 100, including the break away split coupler 105 and the break away spline receiver 150, may be highly
25 manufacturable, and may be manufactured using a computer numerical control (CNC) lathe or screw machine. Such manufacturing processes allow for the manufacture of double cam lobe 135 shape of the drive feature. Further, during manufacture, the breaking torque of the break away spline coupler 105 may be calibrated within one foot-pound of a desired torque.

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Therefore, the torque-limiting coupling 100, including the break away spline coupler 105 and the break away spline receiver 150, act as an inexpensive mechanical fuse that can be scaled up or down to adapt to many applications. A number of such application are discussed below.

5 In a first example embodiment, an irrigation pump employing a torque-limiting coupling 100 according to the present invention and includes an expensive impeller. During operation of the pump, it draws in a stone that enters the impeller housing, or the intake becomes clogged by another means. The expensive impeller is, thus, unable to continue operating an experiences an increased torque. The break away split coupler
10 105 breaks instantaneously, therefore becoming a sacrificial link and preventing serious damage to the expensive impeller. Traditional devices, such as a "slip clutch," however, would overheat and cause strain to the driving motor or engine maintaining torque on the pump.

 In a second example embodiment, a farming machine, such as a tractor with a
15 rotary cultivator, for example, strikes a stump or a large stone while being used in the field. Typically, it is the weakest link in a drive system that fails. If this weakest link is in the transmission, expensive damage is likely to occur. Further, if this weakest link is in an exposed universal joint on a spinning drive shaft, replacement of damaged parts can be expensive, and bystanders are put at risk of being struck by fragments from the
20 broken component. Moreover, if the weakest link is a tine on the cultivator, the tine may be broken or bent. However, a torque-limiting coupling 100 according to the present invention, including the break away spline coupler 105 and break away spline receiver 150, mounted at the output of the transmission or, alternatively, at the input of the implement, becomes a mechanical fuse that breaks instantaneously preventing
25 damage to the rest of the machine and can be replaced quickly.

 Further, consider a situation in which a power boat or fishing vessel veers off course and strikes a reef. It is well-known that the propeller of a large boat can be an extremely expensive part, and that repair can be costly, both as a direct result of parts and labor for the repair and opportunity cost caused by the boat being unavailable for
30 use. Further, being stranded at sea has its obvious disadvantages and perils. However,

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a torque-limiting coupling 100 according to the present invention, including the break away spline coupler 105 and break away spline receiver 150, can react faster than other failsafe items that may be present, including slip clutches and other break-away rubber couplings, and can be replaced more easily and economically.

5 Moreover, a torque-limiting coupling 100 according to the present invention, including the break away spline coupler 105 and break away spline receiver 150, may be used on any type of machinery in which human body parts may be introduced accidentally, thereby causing an increase in a torsion load experienced by the machinery. In such a situation, the faster the machinery is able to react to the increased
10 torsion load by shutting down, the less trauma will be experienced by a victim whose body parts were caught in the machinery. Therefore, tuning the break away spline coupler 105, such as by adjusting the depth of the bore 120 (*e.g.*, shallower or deeper into the break away spline coupler 105) and changing the diameter of the neck region 125, to an exact predictable limit can prevent serious bodily harm and even save lives.

15 While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

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CLAIMS

What is claimed is:

1. A torque-limiting coupler comprising:
a first end configured to mate to a first receiver coaxially located in a
5 first component configured to rotate;
a second end configured to mate to a second receiver coaxially located in
a second component configured to rotate; and
a neck region between the first and second ends, configured to
experience higher shear stresses than the first and second ends when torque is
10 applied.
2. The coupler of Claim 1 wherein the first end includes a spline fitting.
3. The coupler of Claim 2 wherein the spline fitting conforms to the AND20000
15 mounting convention.
4. The coupler of Claim 1 wherein the second end includes at least one cam lobe.
5. The coupler of Claim 1 wherein the second end includes two opposing cams.
20
6. The coupler of Claim 1 further comprising a band of material surrounding at
least a portion of the second end, the band of material having a softer durometer
than the material of the second end.
- 25 7. The coupler of Claim 6 wherein the band of material is a rubber ring.
8. The coupler of Claim 7 wherein the rubber is Viton.

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9. The coupler of Claim 1 wherein the neck region includes a portion with a smaller cross-sectional area than either the first end or the second end.
10. The couple of Claim 9 wherein the portion with the smaller cross-sectional area
5 has a smaller outer diameter than either the first end or the second end.
11. The coupler of Claim 9 wherein the portion with the smaller cross-sectional area includes a bore.
- 10 12. A method of coupling two components configured to rotate, the method comprising:
coupling a first end of a torque-limiting coupler to a first receiver
coaxially located in a first component ;
coupling a second receiver coaxially to a second component; and
15 coupling a second end of the torque-limiting coupler to the second
receiver in a manner such that a neck region between the first and second ends
of the torque-limiting coupler experiences higher shear stresses than the first and
second components when a torque is applied.
- 20 13. The method of Claim 12 wherein the first end includes a spline fitting.
14. The method of Claim 13 wherein the spline fitting conforms to the AND20000
mounting convention.
- 25 15. The method of Claim 12 wherein the second end includes at least one cam lobe.
16. The method of Claim 12 wherein the second end includes two opposing cams.

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17. The method of Claim 12 further comprising surrounding at least a portion of the second end with a band of material having a softer durometer than the material of the second end.
- 5 18. The method of Claim 17 wherein the band of material is a rubber ring.
19. The method of Claim 18 wherein the rubber is Viton.
20. The method of Claim 12 further comprising adjusting the neck region to have a portion with a smaller cross-sectional area than either the first end or the second end.
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21. The couple of Claim 20 wherein the portion with the smaller cross-sectional area has a smaller outer diameter than either the first end or the second end.
- 15
22. The method of Claim 20 wherein the portion with the smaller cross-sectional area includes a bore.
23. A system for transmitting torque, the system comprising:
- 20 a first rotating component having a first axially-centered receiver port including splines;
- a second rotating component having a second axially-centered receiver port, the second receiver port having a perimeter profile with varying distances from the axis of rotation; and
- 25 a torque-limiting coupler having a first end with splines configured to be inserted into and mating with the splines included on the first receiver port on the first rotating component, and a second end with a profile corresponding to the perimeter profile of the second receiver port and configured to be inserted into the second receiver port, the first and second ends coupled to a neck region

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configured to experience higher shear loads than the first and second ends when torque is applied.

24. The system of Claim 23 wherein the splines conform to the AND20000
5 mounting convention.
25. The system of Claim 23 wherein the profile of the second end includes a cam lobe.
- 10 26. The system of Claim 23 further comprising a band of material surrounding at least a portion of the second end, the band of material having a softer durometer than the material of the second end.
27. The coupler of Claim 26 wherein the band of material is a rubber ring.
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28. The coupler of Claim 27 wherein the rubber is Viton.
29. The coupler of Claim 23 wherein the neck region includes a portion with a smaller cross-sectional area than either the first end or the second end.
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30. The couple of Claim 29 wherein the portion with the smaller cross-sectional area has a smaller outer diameter than either the first end or the second end.
31. The coupler of Claim 29 wherein the portion with the smaller cross-sectional
25 area includes a bore.
32. A method of manufacturing a torque-limiting coupler, the method comprising:
providing a first end of the torque-limiting coupler;
providing a second end of the torque-limiting coupler;
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adjusting the depth of an axial bore from the first end of the torque-limiting coupler toward a neck region of the torque limiting coupler located between the first and second ends of the torque limiting coupler; and

5 adjusting the outer diameter of the neck region of the torque-limiting coupler, the depth of the axial bore and the outer diameter of the neck region being selectable such that the neck region experiences higher shear stresses than the first and second ends when torque is applied.

10 33. The method of Claim 32 wherein the torque-limiting coupler is manufactured using a computer numerical control (CNC) lathe process.

34. The method of Claim 32 wherein the torque-limiting coupler is manufactured using a screw machine process.

15 35. The method of Claim 32 where adjusting the depth of the axial bore and adjusting the outer diameter of the neck region calibrates a breaking torque of the torque-limiting coupler to within one foot-pound of a desired torque.