

MODULAR CRANKSHAFT

Inventors: Omar M Kabir and Kent Pearl

BACKGROUND

5 [0001] The field of this invention is a crankshaft that is in modular form and more specifically relates to a connection technique that approaches the rigidity of a continuous crankshaft while allowing the flexibility to be in modular form.

10 [0002] Crankshafts are generally cast components that accommodate the required number of throws depending on the number of cylinders in the engine or compressor. In large compressor applications, a breakdown can be very expensive for the operator in the form of lost production or other process outage until repairs can be made, for instance. When the repair involves a crankshaft, the downtime can be lengthy because vendors seldom maintain an inventory of replacement crankshafts. Instead, when a replacement crankshaft is desired, it is manufactured from scratch, which can lead to delays and undesired downtimes.

15 [0003] One way to address the variety in the number of throws is to create a modular design where basic components can be assembled to each other to create the requisite configuration for a particular installation. The issue that doing this raises is how to fashion a connection that will be sufficiently rigid to address issues such as alignment, relative rotation and vibration, among other issues. Prior designs have
20 attempted to connect modules with a splined male into female connection, as is described in USP 5,537,971. The problem with this design is the bulkiness of the connection and the clearances in the splined connection that permit assembly but over time can wear to the point of permitting relative rotational movement that can cause vibration and even spline failure, for example. Another solution is depicted in
25 USP 4,622,864. This technique freezes a pin and inserts this frozen pin into aligned bores to put the modules together. This process requires precise alignment of the pin to make sure that lubrication passages through it are not obstructed. In other respects, modular shafts that attach the modules together with threads are known, as shown in a rock breaking tool in USP 4,657,306.

[0004] Therefore, there exists a need for improved modular crankshaft connection techniques.

SUMMARY OF THE INVENTION

[0005] In accordance with certain embodiments, the present invention provides a
5 plug with opposed tapers and spaced seal rings. Hydraulic fluid channels run to the tapered exterior between the seals and spread the opposing receptacles in the adjoining modules to allow insertion of a cylindrical portion of the pin into the respective receptacles. The receptacles are configured to flex in response to hydraulic pressure and to return to the original dimension when such pressure is
10 removed, thus creating an interference fit. The modules are then flanged together with proper torque on the flange bolts. Those skilled in the art will appreciate the various aspects of the present invention from a review of the exemplary embodiments and the drawings that appear below, as well as from the claims.

[0006] By way of example, certain embodiments of the present invention provide a
15 modular crankshaft that features a connection system between modules that features opposed female receptacles. A pin having opposed beveled ends and hydraulic passages therein is inserted into the opposed receptacles. A pair of seals is disposed on the beveled ends and straddles a hydraulic fluid outlet. The crankshaft wall that defines each receptacle is designed to flex in response to applied hydraulic pressure
20 between the seals on the tapered pin portion. A notch at the base of the receptacle in the crankshaft reduces stress concentration and enables the wall defining the crankshaft receptacle to come back when hydraulic pressure through the pin is removed. The opposed crankshaft receptacles are flanged to allow them to be pulled together over the pin. An interference fit results around the pin after the flanges are
25 mated and the hydraulic pressure is removed.

DETAILED DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with
30 reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] Figure 1 is a section view of two modules joined by the attachment of the present invention, in accordance with an embodiment thereof;

[0009] Figure 2 is a detailed view of the exemplary pin that is used in connecting the modules;

5 [0010] Figure 3 is an end view of the pin of Figure 2;

[0011] Figure 4 is a view of the pin part way into opposing receptacles on the crankshaft modules;

[0012] Figure 5 is a detailed view of a pin end of the pin as it is advanced into the receptacle; and

10 [0013] Figure 6 is shows the pin fully advanced as the modules are connected to each other.

DETAILED DESCRIPTION

[0014] The exemplary modular crankshaft 10 has at least two illustrated modules 12 and 14. The connection between them comprises facing end receptacles 16 and 18
15 that receive opposed ends of a pin 20. The exemplary modules have flanges 22 and 24 that can be drawn together over pin 20 to complete the connection. The pin 20 has a system of oil passages 26 through it. Details regarding the pin 20 can be better understood by reference to Figure 2.

[0015] Figure 2 shows the pin 20 having an inlet passage 28 connected to a
20 transverse passage 30. Inlet passage 28 is sealed at 32, and transverse passage 30 is sealed at opposed ends 34 and 36. There are two oil outlet passages 38 and 40 that, as illustrated, are parallel to each other. However, it is worth noting that these passages may intersect and may be disposed in the same plane or in intersecting planes. Passages 38 and 40 can have one or more outlets on the outer surface 42 of
25 the pin 20. Ends 44 and 46, as illustrated, present a reduced dimension when compared to the main portion 48 of the pin 20 that is located between them. That is, ends 44 and 46 present a frusto-conical section forming a truncated segment of a cone, but other shapes are contemplated. This reduced diameter profile at ends 44 and 46 facilitates interference free insertion into receptacles 16 and 18, although

some interference on seals 50 and 52 at one end and seals 54 and 56 at the other end is contemplated and, in fact, desired for sealing pressure. Figure 3 shows seals 50 and 52 on the reduced dimension portion 46. In the exemplary embodiment, the opposed end view is the same, but the invention contemplates different end treatments in accomplishing the reduced dimension. With regard to the main portion 48, the receptacles 16 and 18 can be similarly shaped. However, the main point is that the shapes of the main portion 48 and the receptacles 16 and 18 be compatible so that they ultimately produce an interference fit around main portion 48. Accordingly, other compatible cross-sectional shapes besides round are contemplated.

[0016] Figures 4 and 5 illustrate the assembly technique in more detail. Figure 4 also illustrates exemplary circumferential recesses 58 and 60 that have a U-shaped cross-section. These recesses 58 and 60 serve to reduce stress concentrations at bottoms 62 and 64 of receptacles 18 and 16 when their dimension is enlarged so that the receptacles will elastically return to their original dimensions around pin 20 when oil pressure is removed, instead of plastically deforming under applied oil pressure. As shown in Figure 4, ends 44 and 46 have reduced dimension to allow them to readily enter the receptacles 16 and 18. At some point of insertion, seals 50 and 52, for example, make contact with receptacle 18, while the same result occurs at the other end of pin 20 as nut 68 is rotated on threaded rod 66 bringing flanges 22 and 24 closer together. Bolts and nuts can be used as an alternative. Figure 5 shows seals 50 and 52 contacting receptacle 18 as oil is applied under pressure through passage 38. The oil under pressure elastically enlarges the dimension of the receptacle 18 as well as the receptacle 16 through passage 40. As a result, the main portion 48 does not drag or only minimally contacts the surrounding receptacle as the flanges 22 and 24 are brought together with the oil pressure applied to passages 38 and 40 between seal pairs at opposed ends of the pin 20.

[0017] Figure 6 illustrates the fully mated position of flanges 22 and 24. It should be noted that oil pressure is applied until the flanges mate to keep the receptacles 16 and 18 elastically enlarged to avoid hanging the pin 20 in either receptacle. As soon as the nut 68 is torqued to specification, the oil pressure is relieved and the presence of

recesses 58 and 60 facilitate the elastic return to the original dimension for receptacles 16 and 18. The end result is that an interference fit is created in the zone 70 that generally corresponds to main portion 48. The modules 12 and 14 are now fully assembled. The oil line (not shown) is disconnected and capped. Those skilled in the art will appreciate that the oil inlet connection is placed adjacent a gap in the flanges 22 and 24 to allow oil access while the flanges are pulled together. Additionally, the connection described above can be undone by reversing the process and applying oil pressure while parting the flanges 22 and 24.

[0018] Those skilled in the art will appreciate that the present invention provides a unique way of joining modular crankshaft components for engines or compressors or other power equipment. The technique employs a residual interference fit to better provide continuing alignment and to guard against relative rotation, without the need for splines, for instance. The use of the oil pressure to elastically deform the receptacles allows assembly without specialized tools and shortens the time required for assembly. The recesses at the base of the receptacles 16 and 18 mitigate against the occurrence of undesirable plastic deformation and thus provide an interference fit of the pin 20 in receptacles 16 and 18. Two or more modular sections that are alike or unlike can be joined in this manner to accommodate the required number of throws or spacing desired. Pin 20 can be machined or forged. Precision instruments are not required for assembly. The exemplary mating faces 72 and 74 are precision machined so that when they are brought together the modules 12 and 14 are properly aligned. The presence of the pin 20 in receptacles 16 and 18 provides the needed rigidity to the connection under load and reduces the likelihood of deforming or deflecting or flexing under torque to allow the modular components to function as well as a unitary design. Modular components can now be kept on hand to handle a variety of applications with different number of throws so as to reduce inventory costs and to speed up repairs regardless of the crankshaft configuration using the technique of modularity described above.

[0019] While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this

disclosure. It is understood that the invention is not limited to the exemplified embodiments set forth herein but is to be limited only by the scope of the attached claims, including the full range of equivalency to which each element thereof is entitled.

- 5 **[0020]** Again, the above description is illustrative of exemplary embodiments, and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.

CLAIMS

1. A modular crankshaft end connection, comprising:
 - 5 a first modular component having a first end connection;
 - a second modular component having a second end connection;
 - said end connections, when brought together, accepting a connector, without preshrinking said connector;
 - wherein at least one of said end connections comprises a receptacle,
 - 10 wherein the receptacle is configured to be elastically enlarged and said connector comprises a pin insertable therein; and
 - wherein said receptacle comprises a bottom and is formed with a recess mounted externally thereto and in general proximity to said bottom, in use the recess serving to reduce stress concentrations at the bottom of the
 - 15 receptacle, thereby allowing the receptacle to elastically return to its original dimensions.
2. The connection of claim 1, wherein said pin elastically enlarges said receptacle.
- 20 3. The connection of claim 2, comprising at least one passage through said pin having at least one exit positioned to apply pressure to said receptacle to enlarge its dimension.
- 25 4. The connection of claim 3, comprising at least one seal adjacent said exit to direct pressure developed in said passage against the receptacle to enlarge its dimension.
5. The connection of claim 4, wherein said at least one seal comprises a
- 30 pair of seals that are on opposed sides of said exit.

6. The connection of any preceding claim, wherein both end connections comprise a receptacle and further comprise a flange adjacent an entrance to each respective receptacle connectable by at least one bolt or stud; whereupon said pin is fully inserted into said receptacles, when aligned, upon
5 said flanges being drawn together by said bolt or stud.

7. The connection of claim 6, where said receptacles are expanded as they are drawn over said pin.

10 8. The connection of claim 7, wherein the pin comprises opposed reduced dimension end segments to facilitate initial insertion into opposed receptacles.

9. The connection of claim 8, wherein the pin comprises conduits having exits at said reduced dimension segments to facilitate pressure transmission.
15 to the receptacles to expand them to the point of allowing a larger main portion of the pin to pass into said receptacles without interference.

10. The connection of claim 9, further comprising seals straddling exits of said conduits in said reduced dimension segments to allow pressurizing and
20 flexing of said receptacles as they are advanced over the pin.

11. The connection of claim 10, wherein said larger main portion of said pin conforms to the shape of a surrounding receptacle but having a larger dimension than said receptacle before said receptacle is elastically enlarged
25 such that upon removal of pressure through said conduits an interference fit is formed on said main portion in said receptacles; said first and second end connections featuring a recess mounted exterior to each receptacle to facilitate expansion in the elastic range when pressure is applied in said conduits.

30