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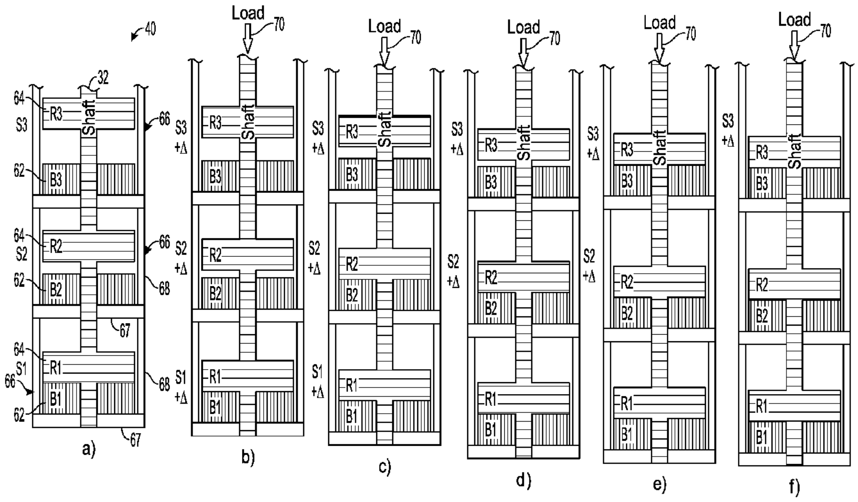

FIG. 2

(57) Abstract: A technique facilitates controlled distribution and sharing of bearing loading with respect to operation of a pump. A thrust bearing system is coupled with a pump via a shaft used for driving the pump. The thrust bearing system comprises a series of thrust bearings which cooperate with a plurality of resilient members. The resilient members are constructed to control loading of the thrust bearings. Effectively, the configuration and elasticity of the resilient members may be selected to provide a desired changing of loading across the series of thrust bearings during startup and operation of the pump.

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ENHANCED THRUST BEARING SYSTEM

BACKGROUND

[0001] In many hydrocarbon well applications, electric submersible pumping (ESP) systems are used for pumping of fluids, e.g. hydrocarbon-based fluids. For example, an ESP system may be conveyed downhole and used to pump oil from a downhole wellbore location to a surface collection location along a fluid flow path. ESP systems often comprise compression pumps which rely on thrust bearings to handle the down thrust generated by the pumps during operation. In many ESP systems, the thrust bearings are located inside a motor protector filled with clean oil to enable operation of the thrust bearings in the clean oil. However, if there are a plurality of motor protectors or if a motor protector utilizes a plurality of sequential thrust bearings, a desirable load sharing between the thrust bearings is difficult to achieve. The thrust bearings also can suffer from excessive wear prior to establishing a fluid oil film along the thrust bearings after startup of the ESP system.

SUMMARY

[0002] In general, a system and methodology facilitate desired distribution and sharing of loading resulting from operation of a pump. A thrust bearing system is coupled with a pump via a shaft used for driving the pump. The thrust bearing system comprises a series of thrust bearings which cooperate with a plurality of resilient

members. The resilient members are constructed to control loading of the thrust bearings. For example, the configuration and elasticity of the resilient members may be selected to provide a desired changing of loading across the series of thrust bearings during startup and operation of the pump.

[0003] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0005] Figure 1 is a schematic illustration of a well system comprising an example of an electric submersible pumping system positioned in a borehole, e.g. a wellbore, according to an embodiment of the disclosure;

[0006] Figure 2 is a schematic illustration of an example of a thrust bearing system during sequential stages of loading, according to an embodiment of the disclosure;

[0007] Figure 3 is a schematic illustration of another example of the thrust bearing system, according to an embodiment of the disclosure;

[0008] Figure 4 is a schematic illustration of another example of the thrust bearing system, according to an embodiment of the disclosure;

[0009] Figure 5 is a schematic illustration of another example of a thrust bearing system during sequential stages of loading, according to an embodiment of the disclosure;

[0010] Figure 6 is a schematic illustration of another example of a thrust bearing system during sequential stages of loading, according to an embodiment of the disclosure;

[0011] Figure 7 is a schematic illustration of another example of a thrust bearing system during sequential stages of loading, according to an embodiment of the disclosure; and

[0012] Figure 8 is a schematic illustration of another example of a thrust bearing system during sequential stages of loading, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0013] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0014] The present disclosure generally relates to a system and methodology which can be used to facilitate desired bearing load sharing and/or to prevent wear during startup of the pump. The enhanced methodology of thrust management further provides or enables increased thrust capacity, lower temperatures, delayed well fluid contact with the thrust bearing, lower bearing wear, and/or increased reliability.

[0015] According to an embodiment, the system and methodology facilitate desired distribution and sharing of loading resulting from operation of a pump, e.g a submersible centrifugal pump. A thrust bearing system is coupled with a pump via a shaft used for driving the pump. Depending on the application, the thrust bearing system may be positioned in the pump or in another component of the overall pumping system. For example, the thrust bearing system may be located in a motor protector or other component of an electric submersible pumping system.

[0016] The thrust bearing system comprises a series of thrust bearings which cooperate with a plurality of resilient members. The resilient members are constructed to control loading of the thrust bearings and may be configured for use in tension and/or compression. As explained in greater detail below, the configuration and rigidity/elasticity of the resilient members may be selected to provide a desired changing of loading, e.g. balancing of loading, across the series of thrust bearings during startup and operation of the pump.

[0017] In a specific embodiment, a plurality of motor protectors may be utilized in an electric submersible pumping system having a submersible motor driving a submersible, centrifugal pump. In this embodiment, a thrust bearing system is utilized in the downhole motor protector, e.g. bottom motor protector, and has a thrust bearing system with a plurality of thrust bearings. By way of example, the plurality of thrust bearings may be located at a lower end of the downhole protector. The thrust bearing system employs a plurality of resilient members configured to enable a desired load sharing between the plurality of thrust bearings. This type of embodiment also enables removal of the thrust bearing from the uphole protector or protectors.

[0018] Referring generally to Figure 1, an example of a well system 20 is illustrated as deployed in a borehole 22, e.g. a wellbore. In this embodiment, the well system 20 may comprise an electric submersible pumping system 24 having a variety of components selected according to the particular application and/or environment in which it is operated. The illustrated electric submersible pumping system 24 comprises a submersible electric motor 26, at least one motor protector 28, and a submersible pump 30 powered by the submersible electric motor 26 via a shaft 32. The shaft 32 may comprise a plurality of joined shaft sections, such as a motor shaft section 34, a motor protector shaft section 36, and a pump shaft section 38. In some embodiments, the submersible pump 30 may be in the form of a centrifugal pump having two or more stages with each stage having an impeller and a diffuser. A thrust bearing system 40 may be used to resist the net thrust load, e.g. down thrust load, resulting from operation of the submersible pump 30. In many applications, the thrust loading is in the form of an axial loading directed along the shaft 32 to the thrust bearing system 40.

[0019] In some embodiments, the electric submersible pumping system 24 may comprise multiple, e.g. redundant, components. For example, a plurality of electric motors 26, motor protectors 28, and/or submersible pumps 30 may be combined to form the electric submersible pumping system 24. According to a specific example, a tandem embodiment utilizes a pair of motor protectors 28. The thrust bearing system 40 may be positioned in, for example, a single motor protector 28 or a plurality of the motor protectors 28. In some embodiments, the thrust bearing system 40 may be located in the downhole, e.g. bottom, motor protector 28 and thrust bearings may be omitted from the other motor protector(s) 28.

[0020] The thrust bearing system 40 also may be positioned in other components of the electric submersible pumping system. For example, the thrust bearing system 40 may be located in submersible electric motor 26, submersible pump 30, and/or other suitable components along the electric submersible pumping system 24, e.g. in a gas handling device, a pump intake, or a dedicated chamber. Additionally, the thrust bearing system 40 may be oriented or re-oriented to provide functions for handling down thrust, up thrust, or both up thrust and down thrust. Multiple thrust bearing systems 40 also may be used in a single electric submersible pumping system 24 or along a single pumping string to provide support for each other and/or redundancy. In some applications, the thrust bearing system 40 may have a dedicated startup bearing, of the same type or a different type from the primary thrust bearing, for specifically handling startup thrust loads of the electric submersible pumping system 24.

[0021] As illustrated, the borehole 22 may be a wellbore drilled into a geologic formation 42 containing a desirable production fluid 44, e.g. petroleum. However, the electric submersible pumping system 24 may be used with a variety of other types of boreholes and other types of fluids. In some applications, the wellbore 22 may be lined with a casing 46 and perforations 48 may be formed through the casing 46 to enable flow of fluid, e.g. production fluid 44, between the surrounding formation 42 and the wellbore 22.

[0022] The electric submersible pumping system 24 may be deployed in borehole 22 via a conveyance system 50 which may have a variety of configurations. For example, conveyance system 50 may comprise tubing 52, e.g. coiled tubing or production tubing, or another suitable conveyance, such as cable. The conveyance system 50 is coupled with electric submersible pumping system 24 by a connector 54.

[0023] Electric power is provided to submersible motor 26 via a power cable 56 so as to operate the submersible motor 26. The submersible motor 26, in turn, powers the operation of submersible pump 30 which is then able to draw in fluid through a pump intake 58 and to discharge the pumped fluid through a discharge 60. The fluid flow pumped through discharge 60 is directed to a desired location, e.g. a desired collection location at a surface of the earth. In the example illustrated, the production fluid flow path is along an interior of tubing 52 but the production fluid flow path can be disposed along an annulus surrounding conveyance 50 or along another suitable passage.

[0024] Referring generally to Figure 2, an embodiment of thrust bearing system 40 is illustrated. In this example, the thrust bearing system 40 is illustrated schematically in various stages of loading along shaft 32. As illustrated, the thrust bearing system 40 comprises a plurality of thrust bearings 62 and a plurality of runners 64. The runners 64 are coupled to the shaft 32 and positioned for engagement with the plurality of corresponding thrust bearings 62. For example, each runner 64 may be positioned for engagement with a specific, corresponding thrust bearing 62.

[0025] The thrust bearing system 40 also comprises a plurality of resilient members 66 which automatically adjust in axial length during axial loading of shaft 32. The resilient members 66 are elastic and thus change in axial length under axial loading of shaft 32 as each successive runner 64 is brought into engagement with and loaded against the corresponding thrust bearing 62. By way of example, each thrust bearing 62 may be coupled with a corresponding resilient member 66 via a mounting structure 67, e.g. a plate or other suitable structure. The elasticity of resilient members 66 may be used to return them to their original length once the axial loading along shaft 32 is removed, e.g. upon stopping operation of pump 30. The configuration and elasticity/rigidity of the resilient members 66 may be used to provide a desired, predetermined distribution of loading between the plurality of runners 64 and thrust bearings 62 during, for example, start up and further operation of submersible pump 30.

[0026] Referring again to the embodiment of Figure 2, at least two thrust bearings 62 are separated by resilient members 66 in the form of stretching elements 68. The stretching elements 68 act in tension during axial loading of shaft 32. In this example, the illustrated bottommost thrust bearing 62 is initially in contact with its corresponding runner 64 while the other thrust bearings 62 are separated from their corresponding runners 64. When the pump 30 is started, a thrust load 70 is generated along shaft 32 and changes the axial length of, e.g. elongates, the resilient members 66/stretching elements 68 until the second thrust bearing 62 is engaged with its corresponding runner 64. As the thrust load 70 continues to increase, the remaining resilient members 66/stretching elements 68 elongate until the remaining thrust bearings 62 are engaged with their corresponding runners 64. The sequential engagement of thrust bearings 62 by corresponding runners 64 is illustrated via the different operational positions of thrust bearing system 40 in the schematic sequence of Figure 2 (moving left to right). Figure 2 illustrates three thrust bearings 62 but other numbers of thrust bearings 62 and corresponding runners 64 may be employed.

[0027] Once a lower thrust bearing 62 is engaged by its corresponding runner 64, that thrust bearing 62 is able to manage the loading along shaft 32 until the next above, sequential thrust bearing 62 is engaged by its corresponding runner 64. After that point, the loading on the lower thrust bearing 62 is not increased (even if the overall thrust loading along shaft 32 increases) because the additional loading on shaft 32 can be managed by the thrust bearing 62 located above. This pattern may be continued until each of the successive thrust bearings 62 is contacted and loaded by its corresponding runner 64.

[0028] Accordingly, the material type, and/or configuration of successive resilient members 66 can be used to control the axial change in length, e.g. elongation, of successive resilient members 66, thus determining the maximum load each thrust bearing 62 manages during startup and continued operation of pump 30. For example, the amount of elongation of the resilient members 66 may be selected to accomplish a desired sequential loading of the thrust bearing 62. Effectively, the elasticity, configuration, and thus elongation of the resilient member 66 may be used to establish a loading logic with respect to load sharing in which successive or “staged” thrust loading occurs across a plurality of thrust bearings 62 according to a desired load sharing.

[0029] In some applications, the resilient members 66 may be used to form an outer housing of a motor protector 28 or of another pumping system component containing thrust bearing system 40. Referring generally to Figure 3, however, an embodiment is illustrated in which the motor protector 28 (or other system component) has a separate outer housing 72. In this example, the resilient members 66 are mounted inside the outer housing 72 via a mounting structure 74. In the embodiment illustrated, the resilient members 66 are again in the form of stretching elements 68 which act in tension sequentially during axial loading of shaft 32. The sequential loading is similar to that described above with respect to the embodiment illustrated in Figure 2.

[0030] By way of example, the series of resilient members 66/stretching elements 68 may be suspended from the mounting structure 74 in general alignment with each other. In some embodiments, however, each thrust bearing 62 may be supported individually by a corresponding resilient member 66/stretching element 68 extending between that particular thrust bearing 62 and the mounting structure 74, as illustrated in Figure 4. The mounting structure 74 may be coupled with outer housing 72 by welding, fasteners, threaded engagement, or other suitable fastening technique.

[0031] As with other embodiments described herein, each resilient member 66 may be individually configured to achieve a desired elongation and thus load ratio for the corresponding individual thrust bearing 62 relative to the other thrust bearings 62. By way of example, each resilient member 66 may be formed in the shape of a plain cylinder having a predetermined cross-section, material, and elasticity. In some applications, the desired elongation/load ratio may be obtained by constructing the cylinder with grooves, slots, rods, pillars, and/or other features that weaken or strengthen its rigidity to achieve the desired elasticity and elongation. In some applications, the resilient members 66 may be formed as or with springs, such as coil or wave springs.

[0032] It should be noted that thrust bearing system 40 may be positioned at a variety of locations with respect to electric submersible pumping system 24. Similarly, electric submersible pumping system 24 may be located in the borehole 22 in a variety of orientations. In some applications, the electric submersible pumping system 24 may be inverted and/or the thrust bearing system 40 may be located at the top side of motor protector 28. In an inverted embodiment, the thrust bearings 62 may be sequentially engaged from top to bottom rather than from bottom to top as illustrated by the sequential loading series of Figure 2. The thrust bearing system 40 also may be oriented or re-oriented to provide functions in down thrust, up thrust, or both up thrust and down thrust directions. Multiple thrust bearing systems 40 also may be used in a single electric submersible pumping system 24 or along a single pumping string to support each other or to provide redundancy. The thrust bearing system 40 also may be located in various components along the electric submersible pumping system 24, e.g. inside submersible motor 26, motor protector 28, submersible pump 30, a pump intake, a gas handling device, and/or a dedicated bearing chamber.

[0033] In some embodiments, such as the embodiment illustrated in Figure 4, each resilient member 66/stretching element 68 may have the same stiffness/elasticity to ultimately provide an equally distributed load across the thrust bearings 62. This type of embodiment may be used, for example, in applications in which loaded components having much higher rigidity than the stretching elements 68. The stretching elements 68, however, still ensure that slight differences in contact and/or spacing are quickly compensated to provide the desired load sharing. If the stretching elements 68 have different, or slightly different, stiffness (e.g. due to manufacturing variance), the load distribution may not be completely even, but still acceptable, across thrust bearings 62. With other embodiments, however, the loading may be intentionally uneven to achieve a desired loading logic and loading distribution for a given application.

[0034] Referring generally to Figure 5, another embodiment of thrust bearing system 40 is illustrated. Figure 5 illustrates a sequence of loading in which thrust bearings 62 are sequentially engaged by corresponding runners 64 as load 70 is applied through shaft 32 during startup and continued operation of pump 30. In this example, the resilient members 66 are in the form of compression elements 76 which act in compression during axial loading of the shaft 72.

[0035] By way of example, each compression element 76 may be positioned between a corresponding thrust bearing 62 and corresponding mounting structure 67. In some applications, the compression elements 76 support the corresponding thrust bearing 62 against a rigid pumping system structure, such as outer housing 72 of motor protector 28. As illustrated in Figure 5, the bottommost thrust bearing 62 is initially in contact with the corresponding runner 64 while the other thrust bearings 62 are separated from their corresponding runners 64. When the pump 30 is started, thrust load 70 is generated along shaft 32, thus loading of the bottommost thrust bearing 62 by the corresponding runner 64. The loading of the bottommost thrust bearing 62 deforms, e.g. axially compresses, the corresponding compression element 76 until the second thrust bearing 62 is engaged by its corresponding runner 64.

[0036] As the thrust load 70 continues to increase, the remaining resilient members 66/compression elements 76 deform and axially compress until the remaining thrust bearings 62 are engaged by their corresponding runners 64. The sequential engagement of thrust bearings 62 with corresponding runners 64 is illustrated by the different operational positions of thrust bearing system 40 in the schematic sequence of Figure 5. Figure 5 illustrates three thrust bearings 62 but other numbers of thrust bearings 62 and corresponding runners 64 may be employed. The material and configuration of each compression element 76 may be tailored to achieve the desired adjustment in axial length under compression so as to achieve a desired load distribution between thrust bearings 62.

[0037] Depending on the application, the arrangement of thrust bearing system 40 as well as the orientation of electric submersible pumping system 24 may be changed. In some embodiments, the thrust bearing system 40 may be configured with compression elements 76 arranged so the thrust bearings 62 may be engaged by corresponding runners 64 from top to bottom rather than from bottom to top. Either tension or compression type resilient elements 66 also may be used in applications in which shaft 32 is loaded from below the thrust bearing.

[0038] Referring generally to Figure 6, another embodiment of thrust bearing system 40 is illustrated. Figure 6 again illustrates a sequential loading embodiment in which thrust bearings 62 are sequentially engaged by corresponding runners 64 as load 70 is applied through shaft 32 during startup and continued operation of pump 30. In this example, the resilient members 66 are again in the form of compression elements 76 which act in compression during axial loading of the shaft 72. However, the compression elements 76 are disposed along shaft 32. For example, the compression elements 76 may be integrally formed sections of shaft 32 located between sequential runners 64.

[0039] As illustrated in Figure 6, the bottommost thrust bearing 62 is initially in contact with the corresponding runner 64 while the other thrust bearings 62 are separated from their corresponding runners 64. When the pump 30 is started, thrust load 70 is generated along shaft 32 and thrust load 70, in turn, loads the bottommost thrust bearing 62 by the corresponding runner 64. The loading of the bottommost thrust bearing 62 deforms, e.g. axially compresses, the corresponding compression element 76 in shaft 32 until the second thrust bearing 62 is engaged by its corresponding runner 64.

[0040] As the thrust load 70 continues to increase, the remaining resilient members 66/compression elements 76 deform and axially compress along shaft 32 until the remaining thrust bearings 62 are engaged by their corresponding runners 64. The sequential engagement of thrust bearings 62 with corresponding runners 64 is illustrated by the different operational positions of thrust bearing system 40 in the schematic sequence of Figure 6. Figure 6 illustrates three thrust bearings 62 but other numbers of thrust bearings 62 and corresponding runners 64 may be employed. Similar to previously described embodiments, the material and configuration of each compression element 76 may be tailored to achieve the desired adjustment in axial length under compression so as to achieve a desired load distribution between thrust bearings 62.

[0041] Once a lower thrust bearing 62 is engaged by its corresponding runner 64, that thrust bearing 62 is able to manage the loading along shaft 32 until the next above, sequential thrust bearing 62 is engaged by its corresponding runner 64. After that point, the loading on the lower thrust bearing 62 is not increased even if the overall thrust loading along shaft 32 increases because the additional loading on shaft 32 can be managed by the thrust bearing 62 located above. This pattern may be continued until each of the successive thrust bearings 62 is contacted and loaded by its corresponding runner 64.

[0042] As with stretching elements 68, the material type, and/or configuration of successive compression elements 76 can be used to control the actual change in length of successive resilient members 66/compression elements 76, thus determining the maximum load each thrust bearing 62 manages during startup and continued operation of pumps 30. For example, the amount of axial compression of compression elements 76 may be selected to accomplish a desired sequential loading of the thrust bearings 62. Effectively, the elasticity, configuration, and compression of the resilient members 66/compression elements 76 may be used to provide the loading logic with respect to load sharing in which successive or "staged" thrust loading occurs across a plurality of the thrust bearings 62 according to a desired load sharing. The loading logic may be selected to load each thrust bearing 62 with approximately the same load or with different loading relative to the other thrust bearings 62.

[0043] In some embodiments, at least two thrust bearings 62 each have a corresponding compression element 76 supporting it against a rigid structure, e.g. housing 72, of the electric submersible pumping system 24. In this particular embodiment, each thrust bearing 62 is initially engaged with its corresponding runner 64 prior to startup of pump 30. An example of this type of thrust bearing system utilizing simultaneous loading of the thrust bearings 62 as pump 30 is started (as opposed to sequential loading) is illustrated in Figure 7. In the embodiment of Figure 7, each compressive element 76 and its surrounding subsystem, e.g. plate 67, may have the same stiffness/resiliency as the other compressive elements 76 and their surrounding subsystems. The arrangement results in an equally distributed load.

[0044] This type of embodiment may be used, for example, in applications in which loaded components have much higher rigidity than the compression elements 76. The compression elements 76, however, still ensure that slight differences in contact and/or spacing are quickly compensated to provide the desired load sharing. If the compression elements 76 have different, or slightly different, stiffness (e.g. due to manufacturing variance), the load distribution may not be completely even, but still acceptable, across thrust bearings 62.

[0045] Referring generally to Figure 8, another example of thrust bearing system 40 is illustrated. In this embodiment, the resilient members 66 comprise both stretching elements 68 and compression elements 76. The stretching elements 68 and compression elements 76 may have various configurations and may be combined in a variety of arrangements to achieve a specific, desired distribution of loading across the thrust bearings 62. This type of embodiment may be used in many types of applications, including applications in which the stiffness/resiliency of the stretching elements 68 and compression elements 76 is similar to the rigidity of the surrounding structural elements. In such a scenario, the stretching elements 68 and compression elements 76 may be configured and arranged to compensate for the similarities in rigidity to achieve a desired load sharing across thrust bearings 62.

[0046] In some embodiments, the resilient members 66 may be constructed to utilize thermal expansion as a mechanism for controlling load distribution. In this example, the stretching elements 68 and/or compression elements 76 react to changes in temperature and those reactions, e.g. changes in axial length, may be used to achieve a desired load sharing. Thermal expansion may be used alone or in combination with elasticity resulting from loading to achieve a desired load distribution.

[0047] By way of example, the resilient members 66 may be constructed from a material or materials having a predetermined thermal coefficient of expansion to enable predetermined changes in axial length. The predetermined changes in axial length may be calculated to cause interaction with the corresponding thrust bearings 62 in a manner enabling a desired, predetermined load sharing as a function of temperature. For example, the increased temperature resulting from operation of submersible motor 26 and motor protector 28 can be used to achieve a desired axial expansion of the resilient member or members 66 corresponding to each thrust bearing 62.

[0048] According to an embodiment, thermal expansion of the resilient members 66 is used to distribute loading as a function of operational heating. Operational heating may result during use of the thrust bearings 62 which increase in temperature as a function of their loading. For example, a hotter bearing creates greater thermal expansion/stretching which, in turn, can be used to distribute loading away from that particular thrust bearing 62. In this fashion, self-regulating load distribution can be achieved by utilizing thermal properties. Depending on the application, the thermal expansion of the resilient members 66 may be an absolute growth value (the resilient member 66 has substantial growth compared to other system elements) or a relative growth value (the resilient member 66 and other system elements grow but the resilient member grows by a greater amount).

[0049] Specific examples have been illustrated and described herein, but other arrangements and configurations of components may be utilized for a given application. For example, the thrust bearing system 40 may be located at other locations within the electric submersible pumping system 24 including pump 30, intake 58, motor protector 28, and/or motor 26. Additionally, multiple thrust bearing systems 40 may be located within the same electric submersible pumping system 24. In some applications, the thrust bearing system or systems 40 may comprise single thrust bearings 62 at different locations within the electric submersible pumping system 24 to achieve a desired load distribution. Also, a plurality of the thrust bearing systems 40, each with a plurality of thrust bearings 62, may be positioned at different locations within the electric submersible pumping system 24. Loading can be shared within each individual thrust bearing system 40 and/or across the plurality of thrust bearing systems 40.

[0050] In some embodiments, the thrust bearing system 40 may include up thrust bearings. Sometimes, the up thrust bearings can be constructed and utilized in a load-sharing capacity. The shaft sections 34, 36, 38 may be coupled together as desired to enable transmission of loading to the thrust bearing system 40 in down thrust applications and/or up thrust applications.

[0051] Some embodiments of thrust bearing system 40 may be constructed to quickly transfer loading from the first engaged thrust bearing 62 to the next sequential thrust bearing 62. When the thrust bearings 62 are sequentially engaged, for example, the first engaged thrust bearing 62 is effectively used as the startup thrust bearing. The corresponding resilient member 66 may be constructed to transition axially relatively quickly to begin load sharing with the next sequential thrust bearing. In this manner, the thrust bearing engaged first can be used as the dedicated startup bearing, thus increasing the reliability and run life of the other thrust bearings 62. In some applications, the type and/or structure of the startup thrust bearing 62 may be of a different nature constructed for specializing in handling startup conditions.

[0052] Additionally, the structure of well system 20 may be adjusted according to the parameters of a given application and/or environment. For example, the electric submersible pumping system 24 may be combined with various other components for use in a wellbore or other type of borehole. The electric submersible pumping system 24 may comprise tandem components, e.g. tandem motor protectors, each with its own thrust bearing system 40. Some applications may utilize additional redundancy and/or other types of components. Similarly, the thrust bearing system(s) may have various arrangements of thrust bearings and corresponding resilient members to provide desired patterns, e.g. logic, with respect to load transition and load sharing.

[0053] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

1. A system for sharing pump loading, comprising:

a pump having a shaft which experiences axial loading during operation of the pump; and

a thrust bearing system coupled to the shaft, the thrust bearing system comprising:

a plurality of thrust bearings;

a plurality of runners coupled to the shaft and positioned for engagement with the plurality of thrust bearings; and

a plurality of resilient members which automatically adjust in axial length during axial loading of the shaft to provide a predetermined distribution of loading between the plurality of runners and the plurality of thrust bearings.

2. The system as recited in claim 1, wherein the pump comprises a centrifugal, submersible pump.

3. The system as recited in claim 2, further comprising a submersible motor and a motor protector, the thrust bearing system being located in the motor protector.

4. The system as recited in claim 3, wherein the shaft comprises a pump shaft section and a motor protector shaft section.

5. The system as recited in claim 1, wherein resilient members of the plurality of resilient members act in tension during axial loading of the shaft.

6. The system as recited in claim 1, wherein resilient members of the plurality of resilient members act in compression during axial loading of the shaft.

7. The system as recited in claim 1, wherein the runners of the plurality of runners sequentially engage thrust bearings of the plurality of thrust bearings as the axial loading of the shaft increases.

8. The system as recited in claim 1, wherein the runners of the plurality of runners simultaneously engage thrust bearings of the plurality of thrust bearings as the axial loading of the shaft increases.

9. The system as recited in claim 1, wherein the plurality of resilient members is located radially inward of a surrounding housing.

10. The system as recited in claim 1, wherein resilient members of the plurality of resilient members form part of the shaft.

11. The system as recited in claim 1, wherein resilient members of the plurality of resilient members have predetermined thermal coefficients of expansion to enable predetermined load sharing as a function of temperature.

12. A method, comprising:

coupling a thrust bearing system with a pump via a shaft used for driving the pump;

providing the thrust bearing system with a series of thrust bearings and corresponding bearing runners; and

utilizing a plurality of resilient members to control engagement of the thrust bearings with the corresponding bearing runners, the elasticity of the resilient members changing loading across the series of thrust bearings and corresponding bearing runners during startup and operation of the pump.

13. The method as recited in claim 12, further comprising positioning the thrust bearing system in at least one of a submersible motor, a motor protector, a submersible pump, a pump intake, a gas handling device, and a dedicated bearing chamber of an electric submersible pumping system.

14. The method as recited in claim 13, wherein coupling the thrust bearing system with the pump comprises coupling the thrust bearing system to a centrifugal pump powered by a submersible motor of the electric submersible pumping system.

15. The method as recited in claim 14, wherein utilizing comprises stretching the resilient members in tension during axial loading along the shaft due to operation of the centrifugal pump.

16. The method as recited in claim 14, wherein utilizing comprises elastically deforming the resilient members in compression during axial loading along the shaft due to operation of the centrifugal pump.

17. The method as recited in claim 14, wherein utilizing comprises stretching at least one of the resilient members in tension during axial loading along the shaft due to operation of the centrifugal pump and axially deforming at least one of the resilient members in compression during the axial loading along the shaft.

18. The method as recited in claim 12, wherein utilizing comprises arranging the resilient members to provide sequential engagement of the thrust bearings and the corresponding bearing runners during startup of the pump.

19. The method as recited in claim 13, wherein coupling comprises arranging the thrust bearing system with a dedicated startup bearing.

20. A system, comprising:

an electric submersible pumping system comprising:

a submersible motor;

a submersible pump powered by the submersible motor via a shaft;

a motor protector; and

a thrust bearing system positioned in the motor protector to counter thrust loading along the shaft when the submersible pump is powered by the submersible motor, the thrust bearing system comprising:

a series of thrust bearings working in cooperation with a plurality of resilient members to change a thrust loading balance across the series of thrust bearings during startup and operation of the submersible pump.

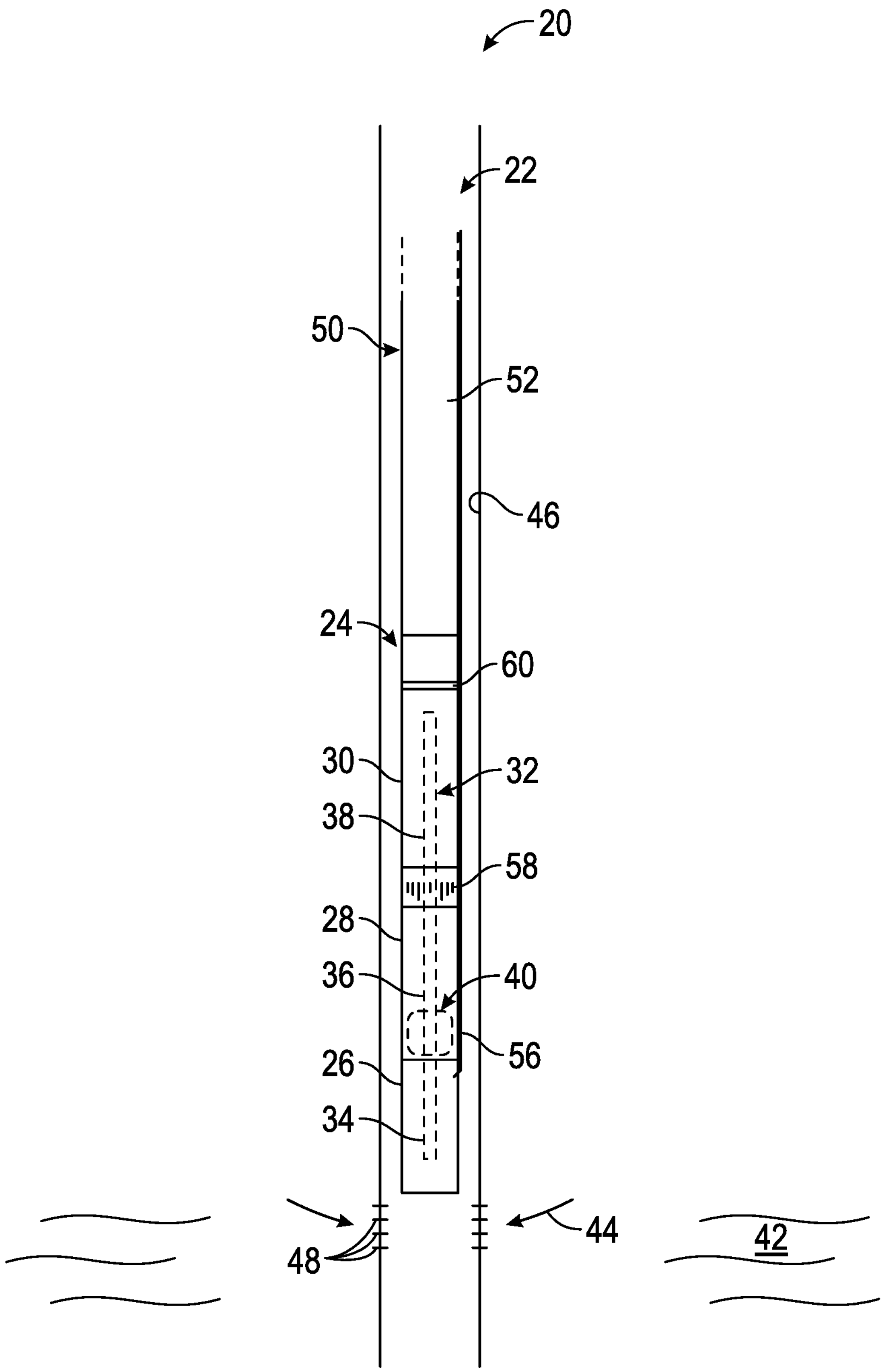

FIG. 1

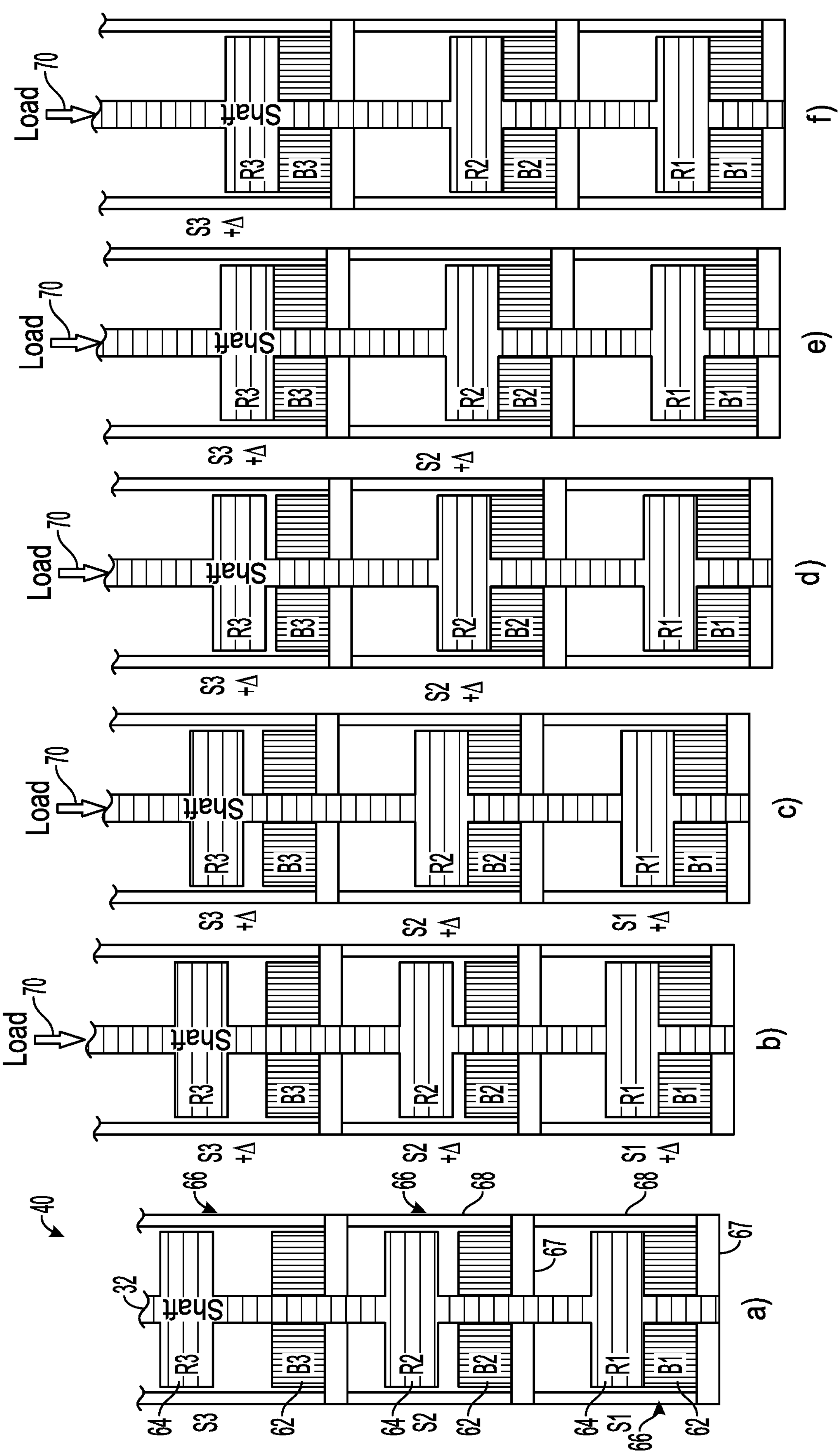
Load
70
Shaft
R1
R2
R3
B1
B2
B3
S1
S2
S3
+Δ
40
32
62
64
66
67
68
a)
b)
c)
d)
e)
f)

FIG. 2

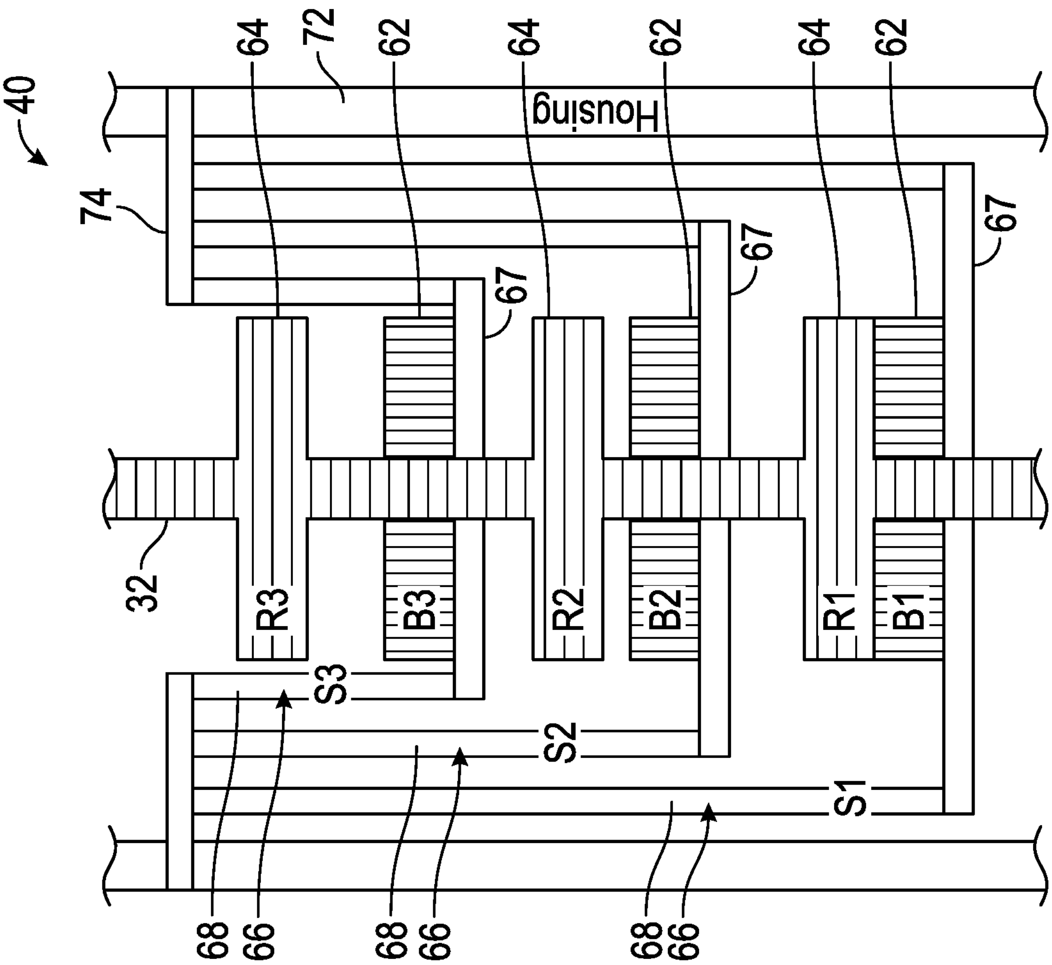
40
74
72
Housing
64
62
67
32
R3
B3
R2
B2
R1
B1
S3
S2
S1
68
66

FIG. 4

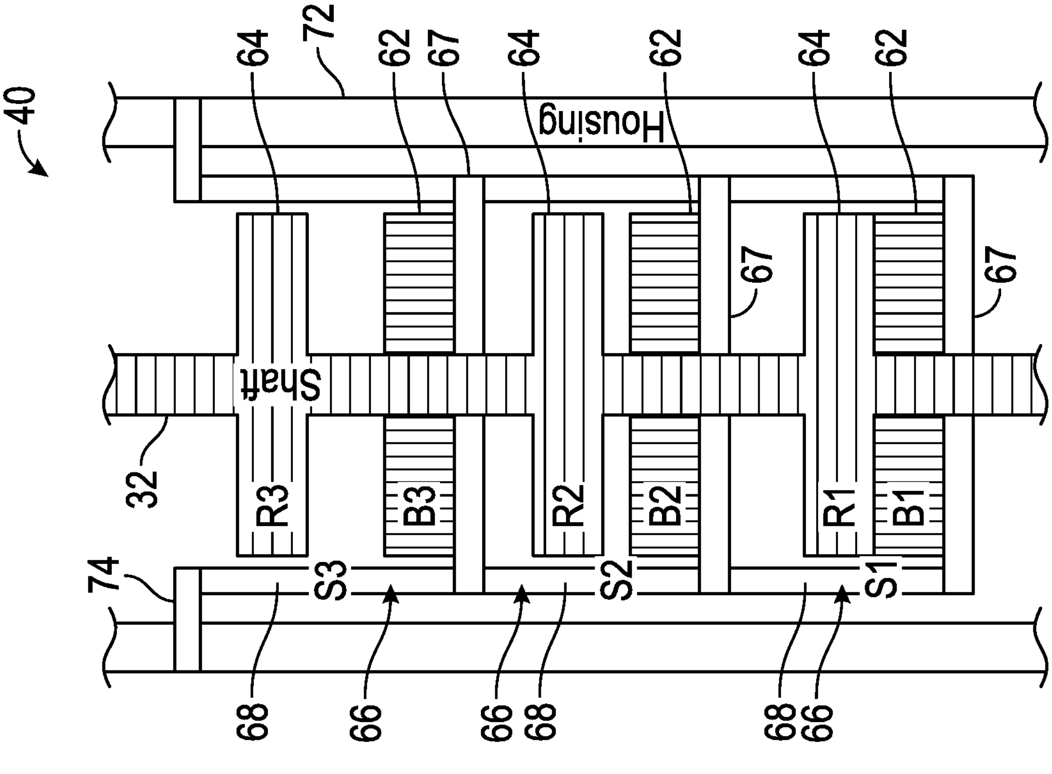
40
74
72
Housing
Shaft
64
62
67
32
R3
B3
R2
B2
R1
B1
S3
S2
S1
68
66

FIG. 3

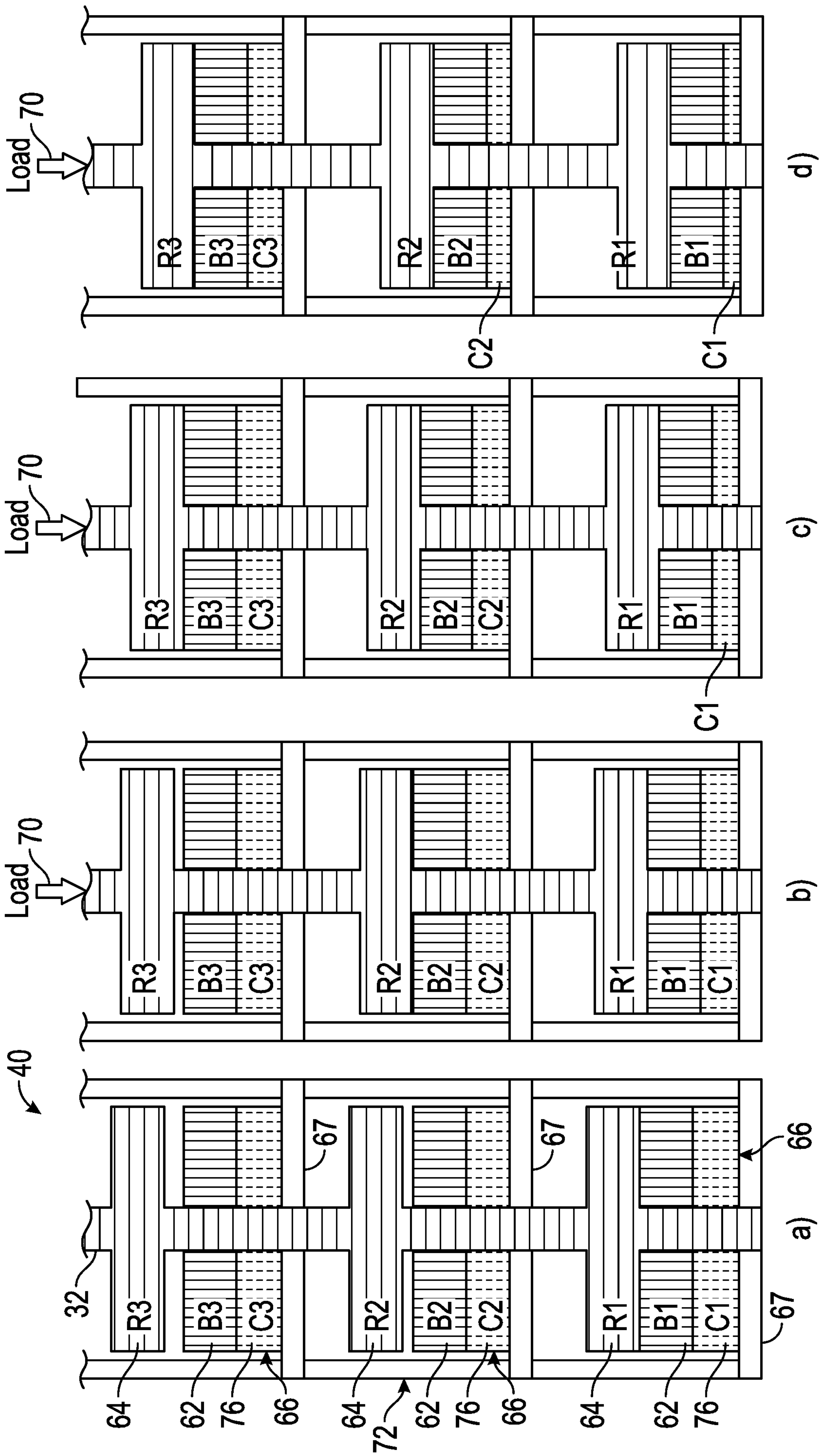

FIG. 5

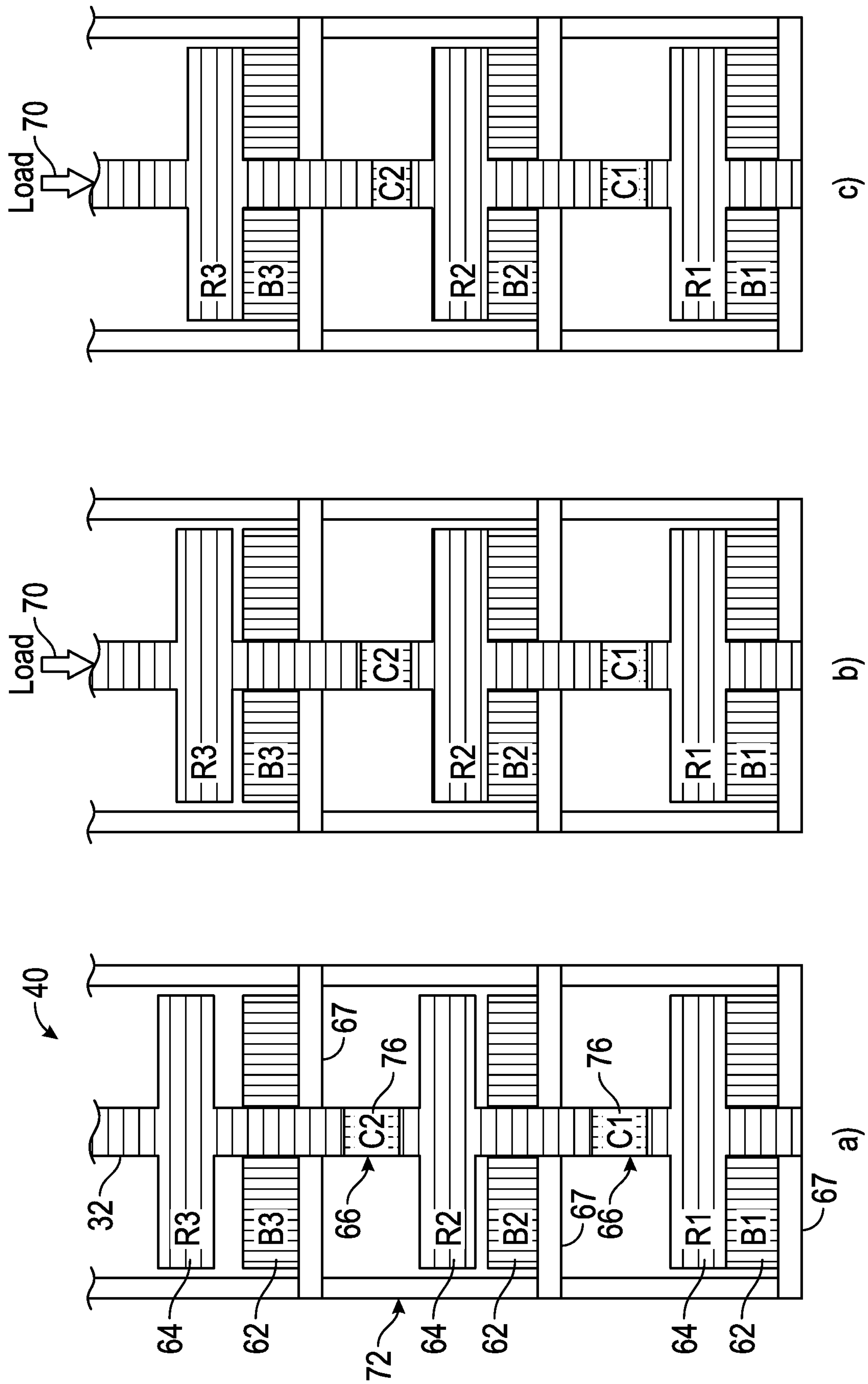

FIG. 6

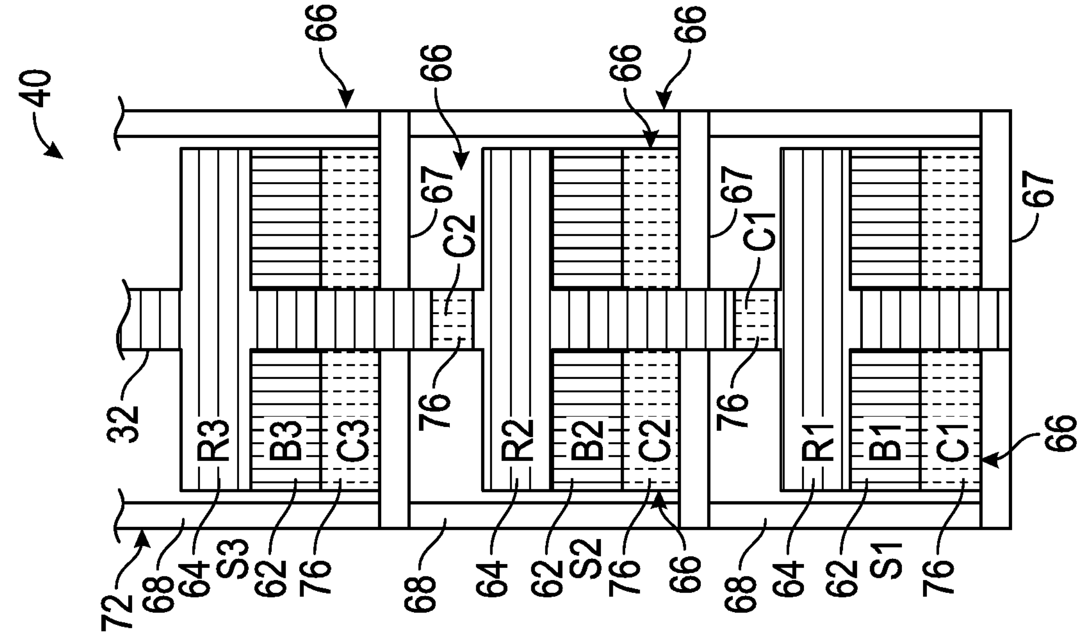
40
66
67
C2
C1
32
76
R3
B3
C3
R2
B2
R1
B1
C1
72
68
64
S3
62
S2
S1

FIG. 8

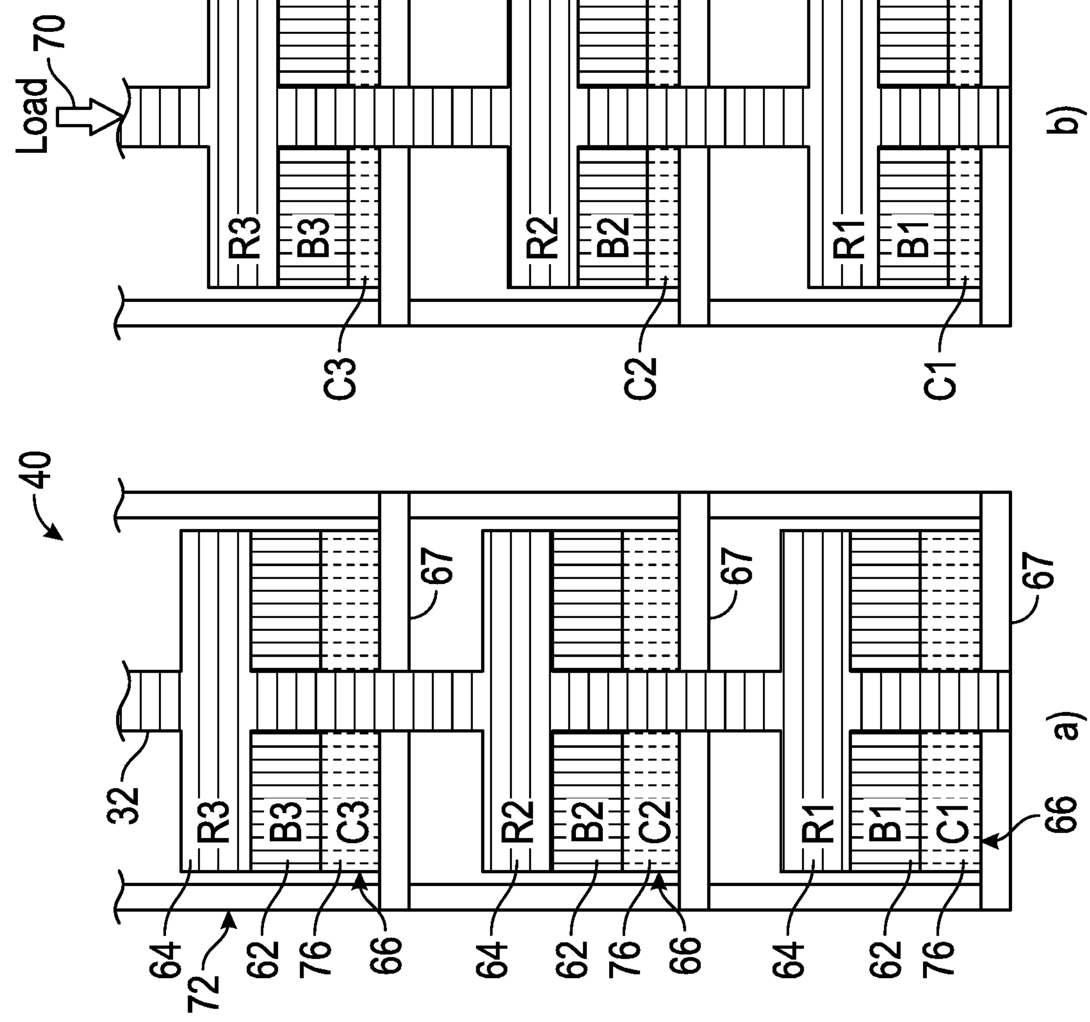
40
Load
70
67
32
R3
B3
C3
R2
B2
C2
R1
B1
C1
66
64
72
62
76
a)
b)

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/026602

A. CLASSIFICATION OF SUBJECT MATTER

F04B 47/06(2006.01)i, F04B 35/04(2006.01)i, E21B 43/12(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B 47/06; F16C 19/02; E21B 33/00; E21B 4/00; E21B 43/00; F16C 17/04; F16C 19/12; F04D 29/04; E21B 17/00; F04B 35/04; E21B 43/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: submersible, sharing, loading, thrust bearing, runner, resilient, motor, and elastic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0078177 A1 (PARMETER et al.) 01 April 2010 see paragraphs [0010]-[0014] and figures 1, 2.	1-20
Y	US 4240683 A (CRASE, GARY M.) 23 December 1980 see column 7, lines 48-62 and figure 2b.	1-20
A	US 5074681 A (TURNER et al.) 24 December 1991 See column 3, line 49 - column 4, line 43 and figure 2.	1-20
A	US 7363975 B2 (LOUGHLIN, MICHAEL J.) 29 April 2008 See column 1, line 63 - column 2, line 36 and figure 1.	1-20
A	US 2012-0107114 A1 (BRUNNER et al.) 03 May 2012 See paragraph [0027] and figure 8.	1-20

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 December 2016 (09.12.2016)	**14 December 2016 (14.12.2016)**

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