Title: GEAR DRIVE SYSTEM AND IMPLEMENTATION THEREOF

Abstract: A fluid displacement device integrates a drive system with a drive gear that directly couples to a motor shaft. The drive system may include a pinion gear that couples with the drive gear. The pinion gear can be configured to transfer rotation of the motor shaft to turn the impeller. In one implementation, the fluid displacement device can embody a centrifugal compressor that requires the impeller to turn at high speeds in excess of 25,000 RPM.
GEAR DRIVE SYSTEM AND IMPLEMENTATION THEREOF

Cross-Reference to Related Application


Field of the Disclosure

[0002] The subject matter disclosed herein relates generally to fluid displacement devices and, more specifically, to a device having a compressor and motor directly coupled together.

Background

[0003] Engineers expend great efforts to improve performance of industrial machines that are configured to move and pressurize fluid (e.g., liquids and gasses). These efforts may focus on various areas including structure and control of the machines, wherein the machines may be "fluid displacement devices" such as pumps, compressors (e.g., centrifugal compressors), and blowers. At least one difference between these different types of machinery resides in the operating pressures of the exit flow that discharges from the machines, e.g., to a process line. Examples of process lines may be found in various applications including chemical, water-treatment, petro-chemical, resource recovery and delivery, refinery, and like sectors and industries. Each area may be useful to increase the operating efficiency with little to no cost to operate the machine.
Summary of the Disclosure

[0004] In view of the foregoing, there is a need in the art for a fluid displacement device having a gear drive system that is configured to reduce parts, costs, and mechanical losses. This configuration may integrate a drive gear directly onto a shaft of a drive motor.

[0005] In one approach according to the disclosure a fluid displacement device includes an impeller and a drive system coupled with the impeller. The drive system includes a drive gear directly mounted to a motor shaft, and a pinion gear coupled with the drive gear, wherein the pinion gear is configured to transfer rotation of the drive gear to turn the impeller.

[0006] In another approach according to the disclosure, a fluid displacement device includes an impeller and a drive system coupled with the impeller. The drive system includes a drive gear directly mounted to a motor shaft of a motive unit, and a pinion gear in mated engagement with the drive gear, wherein the pinion gear is configured to transfer rotation of the drive gear to turn the impeller.

[0007] In another approach according to the disclosure, a method includes providing an impeller and a drive system coupled with the impeller. The drive system includes a drive gear directly mounted to a motor shaft of a motive unit, and a pinion gear engaged with the drive gear. The method further includes transferring rotation of the drive gear through the pinion gear to turn the impeller.
**Brief Description of the Drawings**

[0008] Reference is now made briefly to the accompanying drawings, in which:

[0009] FIG. 1A a perspective view of an exemplary embodiment of a fluid displacement device;

[0010] FIG. 1B is a side view of the exemplary embodiment of the fluid displacement device of FIG. 1A;

[0011] FIG. 2 depicts a perspective view of the fluid displacement device of FIG. 1 in exploded form;

[0012] FIG. 3 depicts an elevation view of the side of the fluid displacement device of FIG. 1 in exploded form;

[0013] FIG. 4 depicts a elevation view of the side of the fluid displacement device of FIG. 1 in partially assembled form;

[0014] FIG. 5 depicts a perspective view of the front of an example of a gear housing for use in the fluid displacement device of FIG. 1;

[0015] FIG. 6 depicts a perspective view of the back of an example of the gear housing of FIG. 5;

[0016] FIG. 7 depicts an elevation view of the cross-section of an example of the gear housing of FIG. 5;
FIG. 8 depicts a perspective view of the front of an example of an interface member for use in the fluid displacement device of FIG. 1;

FIG. 9 depicts a perspective view of the back of an example of the interface member of FIG. 8;

FIG. 10 depicts an elevation view of the cross-section of an example of the interface member of FIG. 8;

FIG. 11 depicts a perspective view of the back of an example of the fluid displacement device of FIG. 1 in partially assembled form; and

FIG. 12 depicts a cross-section of the side of an example of the fluid displacement device of FIG. 1 in partially assembled form;

FIG. 13 depicts a plan view of the cross-section of the fluid displacement device of FIG. 1 in assembled form.

FIG. 14 depicts a cross-section of the side of an example of the fluid displacement device according to embodiments of the disclosure;

FIG. 15 depicts a flow diagram of an exemplary embodiment of a method to drive an impeller in a fluid displacement device.

Where applicable like reference characters designate identical or corresponding components and units throughout the several views, which are not to scale unless otherwise indicated. The embodiments disclosed herein may include elements that appear in one or
more of the several views or in combinations of the several views. Moreover, methods are exemplar
y only and can be modified by, for example, reordering, adding, removing, and/or altering the individual stages.

**Detailed Description**

[0026] The present disclosure will now proceed with reference to the accompanying drawings, in which various approaches are shown. It will be appreciated, however, that the disclosed torch handle may be embodied in many different forms and should not be construed as limited to the approaches set forth herein. Rather, these approaches are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

[0027] As used herein, an element or operation recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural elements or operations, unless such exclusion is explicitly recited. Furthermore, references to "one approach" of the present disclosure are not intended to be interpreted as excluding the existence of additional approaches that also incorporate the recited features.

[0028] Furthermore, spatially relative terms, such as "beneath," "below," "lower," "central," "above," "upper," and the like, may be used herein for ease of describing one element's relationship to another element(s) as illustrated in the figures. It will be
understood that the spatially relative terms may encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures.

[0029] The discussion herein describes embodiments of fluid displacement devices with a gear drive system that is configured to reduce parts, costs, and mechanical losses. This configuration may integrate a drive gear directly onto a shaft of a drive motor (also, "motive unit"). The drive gear couples with a pinion gear that couples with a rotating element such as an impeller. In this way, the gear drive system can transfer rotation of the drive motor to turn the impeller at very high speeds that may exceed 25,000 RPM or more. Furthermore, because the compressor and motor are now integrated as a collective unit, there's no need for a compressor low speed shaft and bearings, or the coupling and coupling guard that connect the compressor and motor.

[0030] Examples of the motive unit include steam turbines, gas turbines, and electric motors. The impeller may have a central body with a plurality of blades disposed thereon. In certain configurations, the blades are exposed. Other configurations enclose the blades on the impeller with a shroud or cover. This shroud secures to the impeller at the top of the blades.

[0031] During operation, rotation of the impeller draws a working fluid into the compressor. The blades are configured to accelerate the working fluid outwardly from the center of rotation, ejecting the working fluid from the impeller under pressure. The compressor directs the working fluid to a discharge. In most configurations, the discharge couples with a pipe that connects the compressor to the process line.
Some embodiments include a drive system that is configured to simplify coupling of the drive motor to the impeller. This feature can offer the following benefits: eliminate couplings and guards, eliminate bearings and power loss, eliminate shafts, e.g., low speed shafts, provide compact design, form splash lubricating system to eliminate oil pumps, provide better fits between drive unit and compressor, and modularize design to include components/cartridges that hold support bearings, shafts, gears, etc. At least these benefits as well as other capabilities may be realized in the disclosed subject matter described herein.

**FIG. 1** illustrates a perspective view of an exemplary embodiment of a fluid displacement device 100 (also "device 100"). This embodiment has a front 102 (also, "first end 102") and a back 104 (also, "second end 104"). On the front 102, the device 100 may have an inlet 106 that allows working fluid F to enter into a volute casing 108. The volute casing 108 is configured to direct the working fluid F to a nozzle member 110. In use, the working fluid F can exit the nozzle member 110 at a discharge 112 having certain desired flow parameters (e.g., flow rate, pressure, etc.). The nozzle member 110 can mate with one or more collateral members (e.g., piping and/or conduit) to discharge the exit flow into a process line. Examples of this process line may be found in various applications including chemical, water-treatment, petro-chemical, resource recovery and delivery, refinery, and like sectors and industries.

**FIGS. 2 and 3** illustrate the device 100 in explode form. Moving from left to right in these diagrams, the device 100 may include an impeller 114...
that couples with a shaft member 116 having a pinion gear 118 disposed thereon. The device 100 can also have a bearing member 119 that can support the shaft member 116. A drive gear 120 can couple with the pinion gear 118 as part of a drive system 121. The device 100 can have a gear housing 122 that houses each of the gears 118, 120. The gear housing 122 can mount to the volute casing 108 and with an interface member 124 that secures to a motive unit 126.

[0035] FIG. 4 illustrates an elevation view of the side of the device 100 in partially assembled view. Several components of the assembly have been removed from view and/or shown in phantom (dashed) lines to clarify the diagram and to help focus the discussion for this particular example. As noted herein, the device 100 employs a drive system 121 to rotate the impeller 114 at high speeds. For centrifugal compressors (and like applications), the device 100 may realize speeds for the impeller 114 in excess of 25,000 RPM. The drive system 121 can include the gears 118, 120 and the motive unit 126. In one implementation, the drive gear 120 may couple directly to the motive unit 126 at an interface 128 between the drive gear 120 and a motor shaft 130. The interface 128 can form a mechanical connection that prevents (and/or reduces) relative movement between the drive gear 120 and the motor shaft 130. In one embodiment, the motor shaft 130 extends through a central opening 123 (FIG. 2) of the drive gear. Examples of this mechanical connection may include a key-and-slot formation, a key-and-shrink fit, interferences fits, set screws, and related modalities to secure the drive gear 120 and the motor shaft 130 to one another to prevent relative movement therebetween.
FIGS. 5, 6, and 7 illustrate an example of the gear housing 122. FIGS. 5 and 6 depict a perspective view of the example from the front 102 and the back 104, respectively. FIG. 7 illustrates an elevation view of the cross-section of the side of the gear housing 122 taken at line 7-7 of FIG. 5.

With reference first to FIG. 5, the gear housing 122 is configured to receive and protect the gears 118, 120 (FIG. 1). The gear housing 122 may have a body 132 with a casing side 134 (also, "first side 134") and an interface side 136 (also, "second side 136"). On the casing side 134, the body 132 may feature a plate member 138 with a plate surface 139 and a first aperture 140 that can receive at least part of the bearing member 119 (FIGS. 2 and 3). The plate member 138 can be generally annular in shape with a plurality of bolt openings 142 disposed proximate the periphery. The bolt openings 142 may form an array that populates the circumference of the plate member 138. This array may be disposed circumferentially about the central aperture 140 and/or otherwise match corresponding openings on the volute casing 108 (FIG. 1).

As best shown in FIG. 6, the bolt openings 142 can penetrate through the plate member 138. This configuration can receive fasteners (e.g., bolts) to couple (or secure or mate) the plate member 138 to the volute casing 108 (FIG. 1). The body 132 may also have a gear member 144 that couples with the plate member 138. The gear member 144 may be cast from one of various materials (e.g., metal) for cost-efficient manufacture. In one implementation, such casting may form the members 138, 144 integrally with one another, although this disclosure does contemplate fabrication of the
gear housing 122 from one or more separate pieces (e.g., the members 138, 144) that affix to one another as a weldment and/or using like fastening techniques. The body 132 may also incorporate a support member 146 interposed between the members 138, 142. The support member 146 may include a generally annular member 148 that aligns with the central aperture 140. One or more leg members 150 can radiate from proximate the annular member 148 outwardly toward the periphery of the plate member 138. The leg members 150 may be spaced annularly apart from one another to form an array that at least partially circumscribes the annular member 148. On the interface side 136, the gear member 144 can have a second aperture 152, which may be larger than the first aperture 140 to receive the drive gear 120. The gear member 144 can also form an interface surface 154 with one or more threaded openings 156 disposed circumferentially about the second aperture 152. The surfaces 139, 154 may be machined and/or result from secondary operation to ensure certain dimensional tolerances (e.g., flatness). This feature can ensure proper fit-up and function of interface member 124, as noted more below.

[0039] FIG. 7 depicts the interior of the gear member 144. As noted herein, the interior may be configured to receive each of the gears 118, 120 (FIG. 1). These configurations can protect the gears 118, 120 from contaminants that can frustrate operation of the device 100. In one implementation, the interior of the gear member 144 may form a chamber 158 or hollow space (or void). This hollow space may be sized to allow the gears 118, 120 (FIG. 1) to mesh and rotate during operation of the device 100. To facilitate assembly of the device 100, the apertures 140, 152 can penetrate the material of the body 132. The first aperture 140 may have a pair of bores (e.g., a first bore 160
and a second bore 162) in a counter-bore arrangement. The larger of the two bores (e.g., the first bore 160) can reside proximate the casing side 134. The smaller of the two bores (e.g., the second bore 162) can reside proximate the chamber 158, terminating at an opening that communicates with the chamber 158. The second aperture 152 can have a third bore 164 that also terminates at an opening that communicates with the chamber 136.

[0040] Also in FIG. 7, some embodiments may include a transitory mount 165 to facilitate movement of the gear housing 122. The transitory mount 165 may include rollers, casters, and like friction-reducing members. In this way, an end user can translate the gear housing 122 relative to (e.g., away from) the volute casing 108 (FIG. 1) to perform certain maintenance and/or repair tasks, as necessary.

[0041] FIGS. 8, 9, and 10 illustrate an example of the interface member 124. FIGS. 8 and 9 depict a perspective view of the example from the front 102 and the back 104, respectively. FIG. 10 illustrates an elevation view of the cross-section of the side of the interface member 124 taken at line 10-10 of FIG. 8.

[0042] Referring first to FIG. 8, the interface member 124 is configured to mate with the gear housing 122 (FIG. 1) and the motive unit 126 (FIG. 1). This example has a body 166 with an interface side 168 and a motor side 170. The body 166 may also be cast, although it is possible to consider use of a weldment and/or like fabricating technique to integrate one or more of the features of the interface member 124 considered herein. In one implementation, the body 166 can comprise a pair of plate members (e.g.,
a first plate member 172 and a second plate member 174). The plate members 172, 174 can be generally annular and/or circular, although this disclosure does contemplate that the geometry of adjacent components (e.g., the gear member 144 (FIG. 6) and/or the motive unit 126 (FIG. 1)) may dictate the form factor for the body 166. The first plate member 172 can have a mating surface 175 with a first aperture 176 that penetrates into the body 166. A plurality of bolt openings 178 may form an array that populates the mating surface 175 of the first plate member 172. This array can at least partially circumscribe the first aperture 176 and can match, at least partially, the array of bolt openings 142 (FIG. 6) on the gear member 144 (FIG. 6) mentioned above. In one implementation, the body 166 can include a frame member 180 that couples the frame members 172, 174. Examples of the frame member 180 may form one or more ribs 182 that interpose between the plate members 172, 174, extending radially away from the central aperture 176. The ribs 182 can be annularly spaced apart from one another to form an array that at least partially circumscribes the central aperture 176.

[0043] FIGS. 9 and 10 provide some additional exemplary features that may be found on the interface member 124. In FIG. 9, the second plate member 174 may have a mating surface 175 with a second aperture 184 that penetrates the body 166. The surfaces 154, 175 may be machine-finished where necessary to hold certain dimension with acceptable tolerances (e.g., flatness). The diagram of FIG. 10 shows that the apertures 176, 184 may form a counter-bore arrangement with a first bore 186 and a second bore 188. The first bore 186 may be generally larger than the second bore 188 so as to potentially receive any protrusions, bosses, and like features that may protrude from
the housing of the motive unit 126 (FIG. 1). The second boss 188 may be sized to receive the shaft 130 (FIG. 4) of the motive unit 126 (FIG. 4). In some embodiments, the bosses 186, 188 may be configured to receive and support bearings that are useful to support the shaft 130 (FIG. 4), as necessary.

FIG. 11 depicts a perspective view of the back of the device 100 in exploded form and with certain members absent for clarity. When assembled, the interface member 124 can mount to the gear member 144, preferably with mating surfaces 154, 175 in contact with one another. Bolts can insert through bolt openings 178. The bolts can be received in the threaded openings 156 to tighten and retain the members 124, 144 in contact with one another.

FIGs. 12-13 show cross-sectional views of the side of the device 100. The interface member 124 is in position on the interface side 134 of the gear housing 122. In one implementation, the shaft member 116 can insert into the first aperture 140 to position the pinion gear 118 in the top portion of the chamber 158. The bearing member 119 can fit into the bores 160, 162 to provide support to the shaft member 116. The assembly may include one or more additional bearings 171 to properly distribute the loading of the shaft member 116 by the pinion gear 118. The drive gear 120 can insert into the third aperture 152. When coupled with the motor shaft 130, the drive gear 120 can reside in the chamber 158 to engage the pinion gear 118. In one example, at the bottom portion of the chamber 158, the members 122, 124 can form a reservoir 192 to retain a volume of fluid 192, preferably lubricant and like viscous fluids sufficient to
cover at least part of the drive gear 120. The lubricant can help prolong the life of mechanical components.

[0046] In one implementation, the device 100 may incorporate a seal that interposes between the surfaces 154, 175. This seal can retain fluid inside of the chamber 158. Another seal may be useful between the plate surface 139 and the corresponding surface on the volute casing 108. Examples of the seals may comprise a compressible unit (e.g., an o-ring, a gasket, etc.) that fits into a groove (or like feature) in one of the mating surfaces 139, 154, and 175. In some implementations, the mating surfaces 139, 154, 175 may be configured to form a metal-to-metal or otherwise forgo use of the seal. As shown in FIG. 13, the device 100 includes a motor shaft bearing member 196 to support the motor shaft 130.

[0047] FIG. 14 shows a cross-sectional partial view of the side of the device 100 according to another embodiment of the disclosure. The interface member 124 is in position on the interface side 134 of the gear housing 122. In one implementation, the shaft member 116 positions the pinion gear 118 in the top portion of the chamber 158. The bearing member 119 can fit into bores to provide support to the shaft member 116. The assembly may include one or more additional bearings 171 to properly distribute the loading of the shaft member 116 by the pinion gear 118. In this embodiment, the bearings 171 are located along the shaft member 116 on both sides of the pinion gear 118.
[0048] Turning now to FIG. 15, a method according to embodiments of the disclosure will be described in greater detail. The method 200 includes providing an impeller and a drive system coupled with the impeller, as shown at block 201. In some embodiments, the drive system includes a gear housing covering the drive gear and the pinion gear, the gear housing including a gear housing plate member, and a central aperture of the gear housing plate member for receiving the shaft member. In some embodiments, the gear housing cover further includes a gear member coupled to the gear housing plate member, wherein the gear member includes an interface surface surrounding a gear opening, the gear opening receiving the drive gear.

[0049] In some embodiments, the drive system further includes an interface member coupled to the motive unit and the gear housing, the interface member including a body and a first interface plate member and a second interface plate member coupled to the body, wherein the first interface plate member has a first mating surface surrounding a first aperture, and wherein the second interface plate member has a second mating surface surrounding a second aperture. In some embodiments, the method further includes coupling the first mating surface directly to the interface surface of the gear member and coupling the second mating surface directly to the motive unit.

[0050] The method 200 further includes directly coupling/mounting a drive gear to a motor shaft of a motive unit, as shown at block 203. The method 200 further includes transferring rotation of the drive gear through the pinion gear to turn the impeller, as shown at block 205.
This written description uses examples to disclose embodiments of the disclosure, including the best mode, and also to enable any person skilled in the art to practice the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.
**Claims**

What is claimed is:

1. A fluid displacement device comprising:
   an impeller and a drive system coupled with the impeller, the drive system including:
   a drive gear directly mounted to a motor shaft; and
   a pinion gear coupled with the drive gear, wherein the pinion gear is configured to transfer rotation of the drive gear to turn the impeller.

2. The fluid displacement device of claim 1, further comprising a shaft of the motor, wherein the drive gear is directly coupled to the shaft.

3. The fluid displacement device of claim 1, further comprising:
   a shaft member coupled to the impeller, wherein the pinion gear is disposed on the shaft member; and
   a bearing member supporting the shaft member.

4. The fluid displacement device of claim 3, further comprising a gear housing covering the drive gear and the pinion gear.

5. The fluid displacement device of claim 4, the gear housing comprising:
   a gear housing plate member;
a central aperture of the gear housing plate member for receiving the shaft member; and

a gear member coupled to the gear housing plate member, wherein the gear member includes an interface surface surrounding a gear opening, the gear opening receiving the drive gear.

6. The fluid displacement device of claim 4, further comprising an interface member coupled to the motor and the gear housing.

7. The fluid displacement device of claim 6, the interface member comprising:

   a body;

   a first interface plate member and a second interface plate member coupled to the body, wherein the first interface plate member has a first mating surface surrounding a first aperture, and wherein the second interface plate member has a second mating surface surrounding a second aperture.

8. The fluid displacement device of claim 7, wherein the first mating surface is directly coupled to the interface surface of the gear member, and wherein the second mating surface is directly coupled to the motor.
9. The fluid displacement device of claim 7, the body comprising one or more support ribs interposed between the first interface plate member and the second interface plate member.

10. The fluid displacement device of claim 1, further comprising:
    a nozzle surrounding the impeller; and
    a volute casing for directing a working fluid to the nozzle.

11. A fluid displacement device comprising:
    an impeller and a drive system coupled with the impeller, the drive system including:
        a drive gear directly mounted to a motor shaft of a motive unit;
        a pinion gear in mated engagement with the drive gear, wherein the pinion gear is configured to transfer rotation of the drive gear to turn the impeller.

12. The fluid displacement device of claim 11, further comprising:
    a shaft member coupled to the impeller, wherein the pinion gear is disposed on the shaft member; and
    a bearing member supporting the shaft member.

13. The fluid displacement device of claim 12, further comprising a gear housing covering the drive gear and the pinion gear, the gear housing comprising:
a gear housing plate member;

a central aperture of the gear housing plate member for receiving the shaft member; and

a gear member coupled to the gear housing plate member, wherein the gear member includes an interface surface surrounding a gear opening, the gear opening receiving the drive gear.

14. The fluid displacement device of claim 13, further comprising an interface member coupled to the motive unit and the gear housing, the interface member comprising:

a body; and

a first interface plate member and a second interface plate member coupled to the body, wherein the first interface plate member has a first mating surface surrounding a first aperture, and wherein the second interface plate member has a second mating surface surrounding a second aperture.

15. The fluid displacement device of claim 14, wherein the first mating surface is directly coupled to the interface surface of the gear member, and wherein the second mating surface is directly coupled to the motive unit.
16. The fluid displacement device of claim 15, the body comprising one or more support ribs interposed between the first interface plate member and the second interface plate member.

17. The fluid displacement device of claim 11, further comprising:

- a nozzle surrounding the impeller; and
- a volute casing for directing a working fluid to the nozzle.

18. A method comprising:

- providing an impeller and a drive system coupled with the impeller, the drive system including:
  - a drive gear directly mounted to a motor shaft of a motive unit; and
  - a pinion gear engaged with the drive gear; and
- transferring rotation of the drive gear through the pinion gear to turn the impeller.

19. The method of claim 18, further comprising:

- providing a gear housing covering the drive gear and the pinion gear, the gear housing including a gear housing plate member having a central aperture;
- receiving the shaft member through the central aperture of the gear housing plate member; and
providing a gear member coupled to the gear housing plate member, wherein the
gear member includes an interface surface surrounding a gear opening, the gear opening receiving the drive gear.

20. The method of claim 19, further comprising providing an interface member coupled to the motive unit and the gear housing, the interface member including:

   a body; and

   a first interface plate member and a second interface plate member coupled to the body, wherein the first interface plate member has a first mating surface surrounding a first aperture, and wherein the second interface plate member has a second mating surface surrounding a second aperture.

21. The method of claim 20, further comprising coupling the first mating surface directly to the interface surface of the gear member and coupling the second mating surface directly to the motive unit.
FIG. 15

200 PROVIDE AN IMPELLER AND A DRIVE SYSTEM COUPLED WITH THE IMPELLER

201 DIRECTLY COUPLED A DRIVE GEAR TO A MOTOR SHAFT OF A MOTIVE UNIT

203 TRANSFER ROTATION OF THE DRIVE GEAR THROUGH THE PINION GEAR TO TURN THE IMPELLER

205
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 16/39001

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8): F04D 29/054 (2016.01)
CPC: F04D 29/054

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)

IPC(8): F04D 29/054 (2016.01)
CPC: F04D 29/054

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC(8): F04D 17/10, F04D 25/02, F04D 25/06, F04D 29/05 (2016.01)
CPC: F04D 17/10, F04D 25/02, F04D 25/06, F04D 29/05 (search term limited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase (all), Google (Web, Patents, Scholar)

Search terms: pinion, bull, gear, electric, motor, compressor, pump, housing, casing, rib

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>US 3,619,086 A (JOHNSON et al) 09 November 1971 (09.11.1971), entire document, especially Abstract, Figs 1-2, col. 2, Ins. 53-54, 56-60, and 64-65</td>
<td>1-6, 10-13, and 17-19</td>
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<tr>
<td>X</td>
<td>US 2012/0107099 A1 (JEONG et al) 03 May 2012 (03.05.2012), entire document, especially Abstract, Figs 1, 3, and 4, paras [0061]-[0067]</td>
<td>1-21</td>
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<tr>
<td>A</td>
<td>US 4,688,989 A (KONDO et al) 25 August 1987 (25.08.1987), entire document</td>
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<tr>
<td>A</td>
<td>US 4,687,414A1A (MAEDA et al) 18 August 1987 (18.08.1987), entire document</td>
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<tr>
<td>A</td>
<td>WO 2014/077311 A1 (MITSUBISHI HEAVY INDUSTRIES, LTD.) 22 May 2014 (22.05.2014), entire document, especially Abstract and Fig 1</td>
<td>1-21</td>
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Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) of which it is cited to establish the publication date of another citation or other special reason (as specified)
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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
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Date of the actual completion of the international search
20 August 2016 (20.08.2016)

Date of mailing of the international search report
5 SEP 2016

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-8300

Authorized officer: Lee W. Young
PCT Helpdesk: 571-272-4300
PCT DSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)