PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :		(11) International Publication Number:
E21B 4/02, F16C 17/10, 17/26	A1	WO 87/ 04486
		(43) International Publication Date: 30 July 1987 (30.07.87)

(21) International Application Number: PCT/US86/02319

(22) International Filing Date: 27 October 1986 (27.10.86)

(31) Priority Application Number: 823,344

(32) Priority Date: 28 January 1986 (28.01.86)

(33) Priority Country: US

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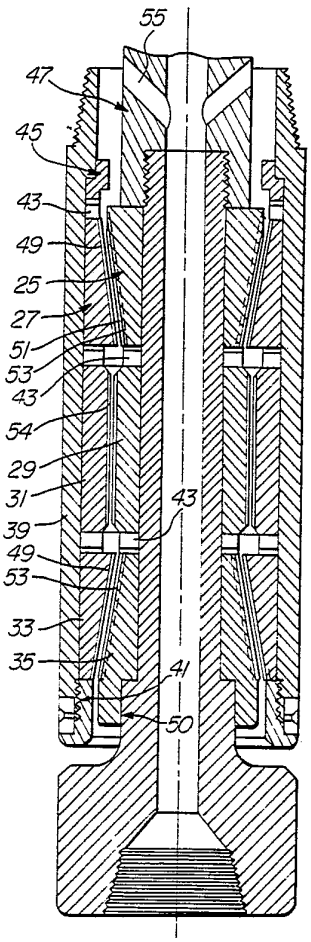
(81) Designated States: AT (European patent), BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), LU (European patent), NL (European patent), NO, SE (European patent).

Published
With international search report.
With amended claims.

(54) Title: TAPERED FRICTION BEARING ASSEMBLY

(57) Abstract

. A bearing structure including first (33, 35) and second (25, 27) tapered bearing surfaces for accommodating on-bottom and off-bottom thrust and radial forces on a drive shaft (17) in a down hole drilling environment and further including a radial bearing (29, 31) mounted between the first (33, 35) and second (25, 27) tapered bearings for restricting bending of the drive shaft (17).



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TAPERED FRICTION BEARING ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The subject invention pertains generally to drilling tools and more particularly to a bearing assembly for accomodating the forces generated in a down hole motor used for example, in the oil drilling arts.

The design of bearing assemblies which will withstand the hostile environments and force loads typically encountered in down hole well drilling present a continuing challenge to the industry. The extremely high temperatures encountered preclude the successful application of sealed bearing technology as it currently exists. Thus, the prior art has turned to bearing structures exposed to the drilling fluids passing through the motor.

2. Description of the Prior Art

In the prior art, a pair of bearings have typically been provided to accomodate the drive shaft and attendant forces thereon. The bearings have been separated such that one bearing accomodates radial forces only and the second accomodates thrust loads only. Typical bearing materials have included poly-crystalline diamonds, ceramics, and tungsten carbide matrix.

It has appeared desirable to the inventor to improve over the prior art bearing structures in order to extend the lifetime of bearings in such apparatus.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide an improved bearing structure.

It is another object of the invention to provide a bearing structure capable of handling both the radial and thrust loads created in a down hole motor.

It is yet another object of the invention to provide a bearing assembly with a longer life than those currently available in the state of the art.

These and other objects are achieved by a bearing assembly having tapered or canted bearing surfaces which absorb both radial and thrust loads. The design provides for a certain amount of fluid flow through the bearing structure with a central radial bearing serving to restrict fluid flow and to eliminate drive shaft deformation in the preferred embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiment for implementing the just summarized invention will now be described in conjunction with the drawings of which:

FIG. 1 is a diagramatic illustration of a down hole drill motor according to the prior art; and

FIG. 2 is a cross sectional drawing illustrating the preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a prior art down hole motor structure wherein the preferred embodiment finds application. As known in the art, the structure includes a progressive cavity motor 13, a coupling 15, a drive shaft 17, and a drill bit 19. The drive shaft 17 is born by a bearing assembly comprising bearings 21 and 23. Typically one of these bearings is a radial bearing and the other is a thrust bearing. In the structure of FIG. 1, radial forces arise from the eccentric motion of the coupling 15 as it is driven by a progressive cavity motor and from the drilling force on the drill bit 19. Thrust forces are generated for example by the pressure differential between points P2 and P3 in FIG. 1. The pressure differential across the bearing assembly is for example, on the order of 200 to 2,000 pounds per square inch (PSI).

FIG. 2 illustrates the preferred embodiment of a tapered friction bearing assembly. The assembly includes an off-bottom thrust and radial bearing 25, 27; a flow restrictor radial bearing 29, 31; and an on-bottom thrust and radial bearing 33 and 35. Each inner bearing element 25, 29, 35, is attached to the drive shaft 17 of the down hole motor.

The outer bearing elements 27, 31, 33 are attached to a housing 39 which is threadably connected to a bottom nut 41. Locks 43 and a lock ring 45 serve to attach the bearings. The inner bearing elements 25, 29, and 35 are further held in position by a shaft cap 47 and are locked to the drive shaft 17 by the eccentric lock surface 50.

The opposing bearing surfaces 49 may be of any suitable bearing surface construction. Such constructions include poly-crystalline diamond, ceramic and

tungsten carbide matrix. Flow grooves 53 are formed in the surfaces 49, 51. These grooves 53 have a width selected to provide sufficient flow of drilling fluid ("mud") to cool and lubricate the bearings. The flow gap 54 between the middle radial bearing elements 29, 31 determines the maximum flow possible. Sufficient pressure drop across the bearings, on the order of minimum 200 PSI, is required to assure sufficient flow of cooling fluid.

In operation, the off-bottom thrust and radial bearing 25, 27 accomodates the forces on the drive shaft 17 when the drive shaft is driven while the drill bit 19 is off-bottom, i.e., disengaged from a drilling operation. The on-bottom thrust and radial bearing 33, 35 accomodates the forces on the drive shaft 17 when the drill bit 19 is on-bottom, engaged in a drilling operation. The radial bearing 29, 31 serves to prevent bending of the drive shaft 17 which would otherwise occur as a result of the varying force pattern to which the drive shaft 17 is exposed. Prevention of bending increases the fatigue lifetime of the system.

The angle of the taper of the bearing elements 25, 27 is determined by the angle with respect to vertical of the resultant force vector on the drive shaft 17 in the off-bottom position. Similarly, the angle of the on-bottom thrust and radial bearing 33, 35 with respect to vertical is determined to match the angle of the resultant force vector typically expected to be experienced by the drive shaft 17 in its running, on-bottom mode. It will be observed that the drive shaft 17 will ride up or down with respect to the housing 39, depending on whether the drill string is in the off-bottom or on-bottom mode and otherwise in response to

the forces experienced by the drive shaft 17. The optimum force balance of course is where the drilling parameters are such that the bearings are required to carry no load, i.e., where the drive shaft "floats."

The structure just described thus accomodates both radial and thrust forces, while preventing bending of the drive shaft 17. The structure is usable in a wide variety of applications including both turbine driven and progressive cavity down hole motors. As will be appreciated, the just described preferred embodiment is susceptible to numerous modifications and adaptations without departing from the scope and spirit of the invention. Therefore, it is to be understood, that within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

CLAIMS

What is Claimed is:

1. A drive assembly comprising;

a drive shaft;

a first bearing means for mounting said drive shaft having respective moving and stationary bearing surfaces angled with respect to the axis of said drive shaft for accomodating both thrust and radial forces on said drive shaft.

2. The drive assembly of claim 1 further including a second bearing means for mounting said drive shaft having respective first and second adjacent bearing surfaces angled with respect to said drive shaft.

3. The drive assembly of claim 2 further including a radial bearing means for mounting said drive shaft.

4. The bearing assembly of claim 3 wherein said radial bearing means is mounted between said first and second bearing means.

5. The drive assembly of claim 4 wherein the respective moving and stationary surfaces and respective first and second surfaces are spaced to provide for fluid flow and wherein said radial bearing means provides a fluid flow path for communicating fluid flow between said first and second radial bearing means.

6. The drive assembly of claim 5 wherein said bearing means includes respective bearing faces and wherein the separation between said bearing faces determines the flow of fluid through said first and second radial bearing means.

7. The drive assembly of claim 6 wherein said drive shaft is hollow and wherein fluid is provided to said fluid flow path from a flow channel means for conducting fluid flow into the interior of said drive shaft.

8. Drilling apparatus comprising:

a progressive cavity motor;

a drive shaft having a central axis;

a coupling means connecting said motor to said drive shaft; and

a first bearing having a first rotating bearing surface attached to said drive shaft and a first stationary bearing surface, said first surfaces being substantially parallel and canted at a first angle with respect to the axis of said drive shaft for absorbing both radial and thrust loads on said drive shaft.

9. The drilling apparatus of claim 8 further including a second bearing having a second rotating bearing surface attached to said drive shaft and a second stationary bearing surface, said second surfaces being substantially parallel to one another and canted at a second angle with respect to the axis of said drive shaft.

10. The drilling apparatus of claim 9 wherein said first and second angles are respectively selected to accomodate off-bottom and on-bottom forces on said drive shaft.

11. The drilling apparatus of claim 10 further including a radial bearing means mounted between said first and second bearings.

12. The drilling apparatus of claim 11 wherein said radial bearing means functions to prevent bending of said drive shaft.

13. The drilling apparatus of claim 12 wherein said first and second bearings and said bearing means include respective communicating fluid flow channels.

AMENDED CLAIMS
[received by the International Bureau on 10 February 1987 (10.02.87); original claims 1-13 cancelled; new claims 14-18 added (4 pages)]

14. A drive assembly comprising:

a housing means;

a drive shaft positioned within said housing

an upper frusto-conical bearing means for mounting said drive shaft with respect to said housing means and for absorbing both thrust and radial loads;

a radial bearing means positioned adjacent and below said upper bearing means for restricting bending of said drive shaft;

a lower frusto-conical bearing means positioned below and adjacent said radial bearing means for mounting said drive shaft with respect to said housing means and for absorbing both thrust and radial loads; and

the upper bearing means, radial bearing means, and lower bearing means further providing a continuous downward cooling fluid flow path of circular cross section therethrough, the radial bearing means further comprising means for regulating said fluid flow.

15. The drive assembly of Claim 14 wherein said drive shaft and housing means form part of a downhole drilling motor and wherein said upper, radial, and lower bearing means comprise the only bearing means for mounting said drive shaft with respect to said housing.

16. A drive assembly comprising:

a housing means;

a drive shaft positioned within said housing means;

an upper bearing means for absorbing both radial and thrust forces, said upper bearing means including:

a first upper bearing element mounted on said drive shaft and having an exterior frusto-conical bearing surface of a first selected taper;

a second upper bearing element on said housing means opposite said first upper bearing element and having an interior frusto-conical opening therein with the same taper as that of said first upper bearing element;

a radial bearing means for restricting bending of said drive shaft; said radial bearing means including:

a first radial bearing element mounted on said drive shaft below and adjacent to said first upper element and providing a first cylindrical radial bearing surface;

a second radial bearing element mounted on said housing means below and adjacent to said second upper element and providing a cylindrical radial bearing surface opposite said first cylindrical radial bearing surface;

a lower bearing means for absorbing both radial and thrust forces, said lower bearing means including:

a first lower bearing element mounted on said drive shaft and having an exterior frusto-conical bearing surface of second selected taper;

a second lower bearing element mounted on said housing means opposite said first lower bearing element and having an interior frusto-conical opening of the same taper as said first lower bearing element; and

the upper bearing means, radial bearing means, and lower bearing means providing a continuous cooling fluid flow path of circular cross section between the bearing elements on said housing means and the bearing elements mounted on said drive shaft, the radial bearing means further regulating the flow of said cooling fluid.

17. The drive assembly of Claim 16 wherein said drive shaft and housing means form part of a downhole drilling motor and wherein said upper, radial, and lower bearing means comprise the only bearing means for mounting said drive shaft with respect to said housing.

18. The drive assembly of Claim 16 wherein said continuous fluid flow path comprises a substantially continuous bearing surface.

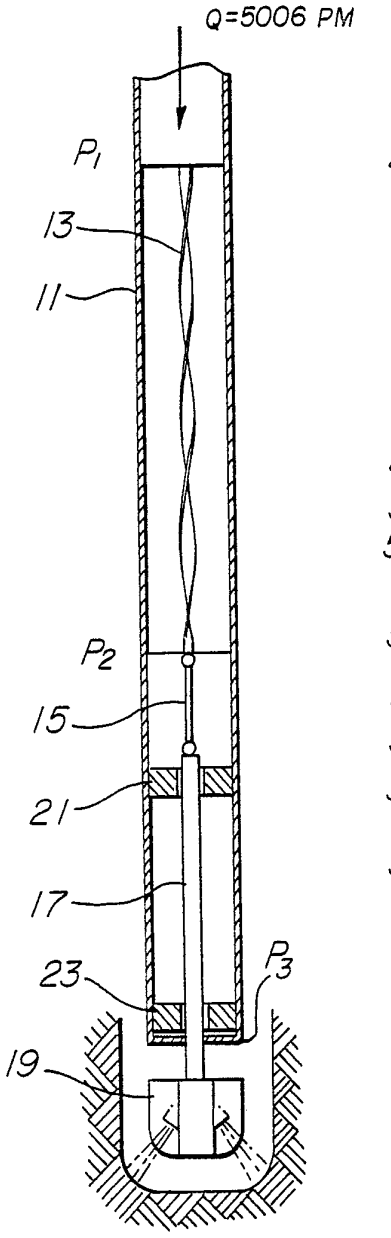

FIG. 1
PRIOR ART

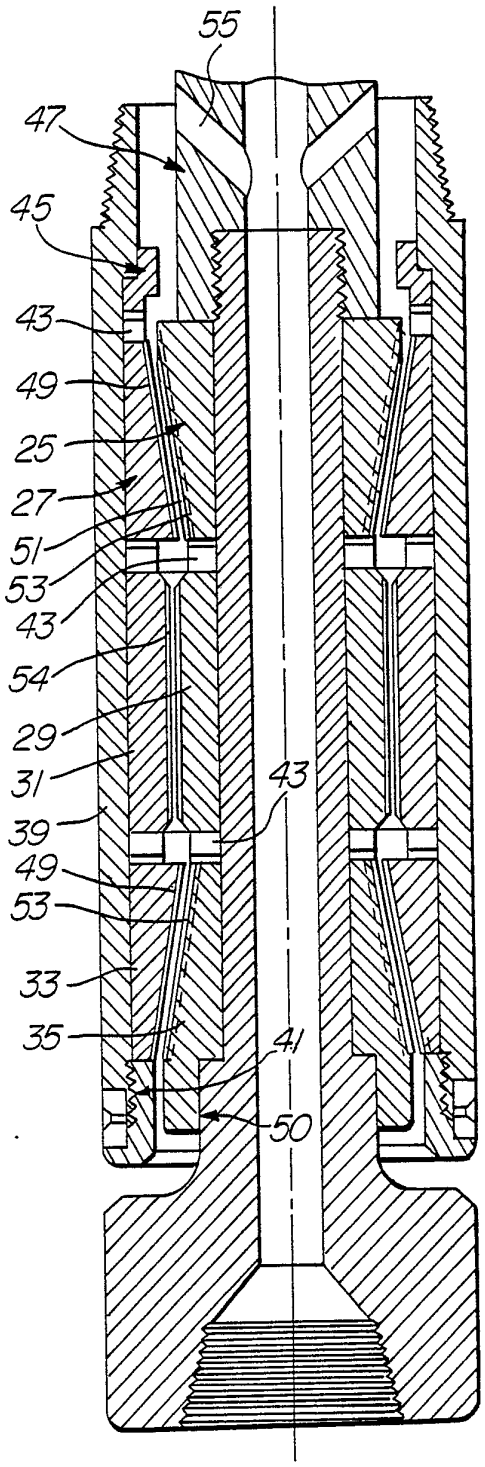

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/US86/02319

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. (4)E21B 4/02; F16C 17/10, F16C 17/26
U.S. Cl. 175/107; 384/110, 384/271

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	175/107; 384/108, 110, 271, 272, 291, 368

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X Y	US, A, 4,410,054 (NAGEL ET AL) 18 Oct. 1983, See column 9 line 1 through column 11 line27	1-3 8-10
X Y	FR, B, 1,171,398 (TIRASPOLSKY ET AL) 26 Jan. 1959, See members 20 and 21 in the sole figure	1-3 8-10
X Y	CA, B, 620,490 (TIRASPOLSKY ET AL) 23 May 1961, See column 2 line 14 through column 3 line 26	1-3 8-10
X	US, A, 3,391,965 (LINDENBOOM) 9 July 1968 See the entire document	1,2
X	US, A, 2,919,960 (WHITNEY) 5 Jan. 1960 See the entire document	1,2
X	US, A, 3,606,501 (WAPLINGTON) 20 Sept. 1971 See the entire document	1,2
A	US, A, 4,518,049 (BALDENKO ET AL) 21 May 1985 See the entire document	8-10

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"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

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
17 December 1986	02 JAN 1987
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Hoang Dang

Form PCT/ISA/210 (second sheet) (October 1981)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, A, 3,484,143 (TALLIAN ET AL) 16 Dec. 1969 See column 9 line 64 through column 10 line 24	1,5-7,13

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ....., because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.