(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 524 413 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
20.04.2005 Bulletin 2005/16

(51) Int Cl.[7]: **F01D 17/16**

(21) Application number: **04256376.7**

(22) Date of filing: **15.10.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

(30) Priority: **15.10.2003 US 685611**

(71) Applicant: **UNITED TECHNOLOGIES CORPORATION**
Hartford, CT 06101 (US)

(72) Inventors:
- **Brooks, Robert T.**
Killingworth CT 06419 (US)
- **Anderson, Stuart A.**
South Windsor CT 06074 (US)

(74) Representative: **Leckey, David H.**
Frank B. Dehn & Co.,
179 Queen Victoria Street
London EC4V 4EL (GB)

(54) **Variable vane electro-graphitic bushing liner**

(57) A method for improving the wear characteristics of bushings comprising the steps of providing a bushing (23) comprising an internal surface having an inner diameter (53) and opposing ends, and pressing a graphite based substance (11) around the internal surface of the bushing (53).

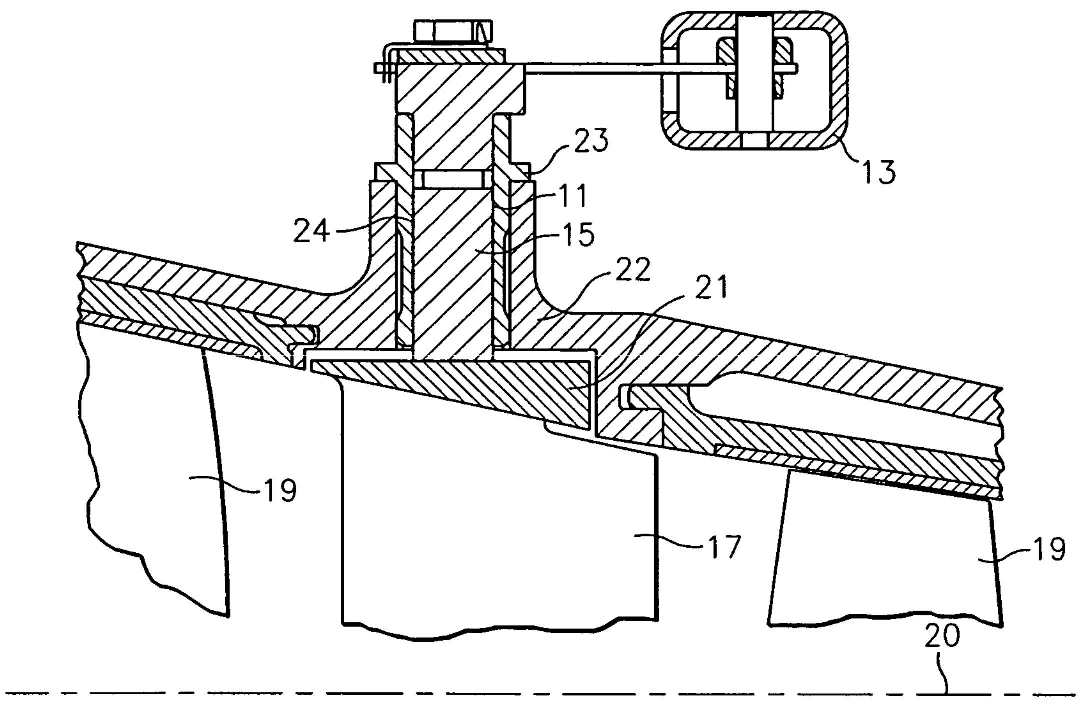

FIG. 1

EP 1 524 413 A2

Description

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The present invention relates to an electrographitic bushing liner for reducing wear in gas turbine trunnions and bushings and a method for producing same.

(2) Description of the Related Art

[0002] In gas turbine engines, the variable vanes of the high compressor are held at the outer diameter by a trunnion bushing. With reference to FIG. 1, there is illustrated the construction of a portion of an engine including the bushing 23. The bushing 23 is situated between trunnion 15 and compressor outer case 22. A variable vane 17 is attached to trunnion 15 via platform 21. On either side of variable vane 17 is a blade 19. Sync ring 13 is attached in such a manner as to enable a rotation of trunnion 15. As a result, the rotation of sync ring 13 provides the synchronized rotation of all variable vanes 17 per Stage. It is critical that the vane to vane angle variation of all variable vanes 17 at one Stage be held at a minimum and maintained at identical angles with respect to the incoming flow of gas. By linking together a multitude of sync rings 13 situated circumferentially about an engine centerline 20, this slight variation in vane angle in each stage may magnify the negative impact on a gas turbine engine performance, and a catastrophic surge may be induced. The trunnion bushing 23 resistant to wear thus has a significant impact on maintaining vane position relative to engine centerline 20.

[0003] The bushing 23 is pressed into the compressor outer case 22 and is typically lined around its internal surface with a wear resistant and low friction material forming bushing lining 24. Typically, bushing lining 24 is a fabric liner (0.018 inches (0.46 mm) thick impregnated with polyimide resin braded carbon fiber) which is bonded into the inner diameter of the bushing 23. Unfortunately, a bushing lining 24 constructed of polyimide resin braded carbon fiber is not capable of withstanding the high temperatures and loads of advanced high performance compressors. At present, bushings 23, to which such a fabric liner has been bonded, are limited to 650°F to 700°F (343°C to 389°C) peak excursions as extended periods of exposure tend to rapidly degrade the liner resulting in metal to metal contact between the trunnion 15 and the bushing 23. Such metal to metal contact serves to wear away the trunnion 15 and the bushing 23 so as to alter the physical geometry of both. As the geometry of the parts change, the tightness of the fit between the bushing 23 and the compressor outer case 22 is similarly altered. Such an alteration in the geometry ultimately results in an angular displacement of a variable vane 17. Such displacement of variable vane 17 can be catastrophic. Specifically, if a variable vane 17 is displaced with respect to adjacent vanes by more than 6°, a catastrophic surge may be induced. It is therefore of the utmost importance that the trunnion 15 and bushing 23 operate in such a manner as to maintain their shapes and, thus, maintain a constant variable vane 17 angle.

[0004] What is therefore needed is a bushing 23 to which is attached a bushing lining 24 which does not suffer material breakdown at high temperatures and which serves to maintain the fit and orientation of bushing 23 and trunnion 15.

SUMMARY OF THE INVENTION

[0005] Accordingly, it is an object of the present invention to provide an electro-graphitic bushing liner for reducing wear in gas turbine trunnions and bushings and a method for producing same.

[0006] In accordance with the present invention, a method for improving the wear characteristics of bushings comprises the steps of providing a bushing comprising an internal surface having an inner diameter and opposing ends, and pressing a graphite based substance around the internal surface of the bushing.

[0007] In accordance with the present invention, a wear resistant bushing comprises a bushing comprising an internal surface having an inner diameter and opposing ends, and a graphite based liner/sleeve pressed around the internal surface of the bushing.

[0008] In accordance with the present invention, a bushing assembly comprises a bushing comprising an internal surface having an inner diameter and opposing ends, a trunnion, and a graphite based liner/sleeve pressed around the internal surface of the bushing in contact with the trunnion and the bushing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 A diagram of the gas turbine engine bushing assembly of the present invention.

FIG. 2 A cross-section diagram of an electro-graphitic carbon liner/sleeve of the present invention.

FIG. 3 A cross-section diagram showing the machining measurements of an electro-graphitic carbon liner/sleeve of the present invention.

FIGS. 4a-4b Graphs illustrating the wear experienced by bushing liners and trunnions known in the art.

FIGS. 5a-5b Graphs illustrating the wear experience by the electro-graphitic carbon liner/sleeve and trunnion of the present invention.

DETAILED DESCRIPTION

[0010] It is a central teaching of the present invention to disclose a bushing 23 into which is press fitted a sleeve composed of a graphite based substance, preferably electro-graphitic carbon. Whereas the prior art made use of a polyimide resin braded carbon fiber which was bonded to the inner diameter of the bushing 23, the electro-graphitic carbon liner/sleeve 11 of the present invention is press fitted about an inner diameter of a bushing 23 of the present invention. The electro-graphitic carbon liner sleeve of the present invention does not suffer significant breakdown even at temperatures approximating 1050°F (566°C). In addition, the electro-graphitic carbon liner/sleeve of the present invention both self lubricates as well as maintains the appropriate distance between the inner diameter of the bushing 23 and the trunnion 15. As a result, the bushing of the present invention may operate for extended periods of time at high temperatures while maintaining its geometry so as to avoid unwanted deflection of the variable vane.

[0011] With reference to FIG. 3, there is illustrated the preferred manner in which the bushing 23 of the present invention is press fitted with the electro-graphitic carbon liner/sleeve 11. In a preferred embodiment, an electro-graphitic carbon rod 51 having a diameter equal to the bushing inner diameter 53 is inserted into the interior of bushing 23 such that opposing ends of the electro-graphitic carbon rod 51 extend beyond normal lines 35. Normal lines 35 extend at a right angle from the sides of bushing 23 at opposing ends of bushing 23. After inserting electro-graphitic carbon rod 51 into the interior of bushing 23, the electro-graphitic carbon rod 51 is cut, or otherwise machined, so as to terminate at each end along a normal line 35. Next, electro-graphitic carbon rod 51 is drilled along bushing centerline 31 to form a hole having a drill hole diameter 41. After drilling to produce a hole having drilled hole diameter 41, the hole is further reamed to form a hole extending along bushing centerline 31 having a diameter equal to ream hole diameter 43. As a result, the difference between ream hole diameter 43 and the bushing inner diameter 53 is equivalent to the thickness of the electro-graphitic carbon liner sleeve which is thus formed pressing against the inner diameter of bushing 23.

[0012] With the electro-graphitic carbon liner sleeve 11 thusly formed, it is preferable to chamfer or otherwise machine the electro-graphitic carbon liner sleeve 11. Were one to allow electro-graphitic carbon liner sleeve 11 to extend at either end parallel to normal line 35, the result would be an increase in the probability of damage to the electro-graphitic carbon liner/sleeve 11. In operation, the stresses transmitted to the trunnion 15 and bushing 23 from the variable vane 17 can be substantial. These forces serve to encourage the trunnion 15 and bushing 23 to rock in a pendulum-like motion away from being parallel to bushing centerline 31. As a result of this rocking motion, severe stress is applied to the ends of the electro-graphitic carbon liner sleeve 11 nearest to normal line 35. If the interior edge of electro-graphitic carbon liner sleeve 11 were to remain a right angle, these forces could cause the electro-graphitic carbon liner sleeve 11 to chip or otherwise fragment. It is therefore preferable to machine a chamfer 37 into the interior edges of electro-graphitic carbon liner sleeve 11. In a preferred embodiment, the angle θ between the chamfered surface 55 of electro-graphitic carbon liner sleeve 11 extending at an angle θ from normal line 35 is between 5 and 85°. Most preferably, the chamfer angle θ is approximately 45°. While illustrated with respect to a chamfer surface 55 extending in a linear fashion at a chamfer angle θ, the present invention is not so limited. Rather, the present invention is drawn broadly to encompass any and all shapes to which chamfer surface 55 might be machined including but not limited to curves. In one embodiment of the present invention, the bushing is fabricated from a titanium based alloy.

[0013] In operation, the bushing 23 of the present invention fitted with the electro-graphitic carbon liner sleeve 11 has been seen to experience no wear of the trunnion after durations of operation in excess of forty hours. It was observed that, as the trunnion rotated and moved with respect to the bushing 23, and subsequently wore upon the electro-graphitic carbon liner/sleeve 11, the electro-graphitic carbon liner sleeve 11 adhered to and filled voids created in the outer surface of the trunnion 15. In this manner, the electro-graphitic carbon liner/sleeve 11 was self lubricating and acted to provide a very stable lubricious graphite-to-graphite contact surface. In addition, as the graphite of the electro-graphitic carbon liner sleeve 11 distributed itself about the trunnion 15, the total volume of the electro-graphitic carbon liner sleeve 11 remained unchanged. As a result, there was maintained a constant spacing between the trunnion 15 and the bushing 23 equal to the original thickness of the electro-graphitic carbon liner sleeve 11. The geometry of the trunnion 15 with respect to the bushing 23 remained constant and therefore avoided any unwanted deflection of the variable vane 17.

[0014] With reference to FIGS. 4a and 4b, there is graphically illustrated the incidence of wear occurring over time with the bushing lining known in the art. As FIG. 4a makes evident, after four hours of operation at 750°F (399°C), both the inner diameter and outer diameter side of the bushing lining exhibited wear between approximately .008 inches (0.2 mm) and .014 inches (0.36 mm). Likewise, as FIG. 4b makes evident, the wear on the trunnion after four hours of operation is approximately .005 inches (0.13 mm).

[0015] In contrast, with reference FIGS. 5a and 5b, there is graphically illustrated the wear experienced when using an electro-graphitic carbon liner/sleeve 11 of the present invention. As can be seen in FIG. 5a, the electro-graphitic carbon liner/sleeve 11 experiences an inner diameter and outer diameter wear after 40 hours of approximately .004 inches (0.1 mm). However, as FIG. 5b makes clear, after 40 hours, the trunnion exhibits no wear. As noted above, this is the result of graphite being detached from the electro-graphitic carbon liner sleeve and redepositing upon the trunnion so as to protect the trunnion. Therefore, while the electro-graphitic carbon liner sleeve 11 of the present invention does exhibit wear, the amount of material worn off is redeposited elsewhere on the trunnion and bushing and does not alter the geometry of the fit between the parts. Therefore, while the electro-graphitic carbon liner sleeve 11 does exhibit wear, the trunnion exhibits no discernible wear at all.

[0016] Further tests conducted at 700°F (371°C) confirm that the electro-graphitic carbon liner sleeve 11 of the present invention exhibits a 3 wear resistance over the bushing lining 24 known in the art over an eight hour period. Even at a temperature of 1050° F (566°C) the electro-graphitic carbon liner/sleeve 11 ran for 24 hours with only 60% of the wear experienced in a comparable polymerized resin fiber bushing lining running for eight hours at only 700°F (371°C).

[0017] In addition, because the electro-graphitic carbon liner sleeve of the present invention is pressed rather than bonded to the metal bushing, it can be pressed out and replaced with a brand new liner. The resultant repaired bushing can be reused for the full life of the engine and is approximately 25% the cost of a new bushing. In addition, the electro-graphitic carbon liner sleeve 11 of the present invention can be machined with very tight tolerances. The current method of bonding a bushing lining as known in the art makes use of a bonded fabric that has less controllable tolerances than a graphite liner of the present invention. A result of the improved tolerance control of the present invention is less wear and improved variable vane position accuracy.

[0018] It is apparent that there has been provided in accordance with the present invention an electro-graphitic bushing liner for reducing wear in gas turbine trunnions and bushings and a method for producing same which fully satisfies the objects, means, and advantages set forth previously herein. While the present invention has been described in the context of specific embodiments thereof, other alternatives, modifications, and variations will become apparent to those skilled in the art having read the foregoing description. Accordingly, it is intended to emb race those alternatives, modifications, and variations as fall within the broad scope of the appended claims.

Claims

1. A method for improving the wear characteristics of bushings comprising the steps of:

providing a bushing (23) comprising an internal surface having an inner diameter (53) and opposing ends; and
pressing a graphite based substance around said internal surface of said bushing (23).

2. The method of claim 1 wherein said providing step comprises providing a turbine engine bushing (23).

3. The method of claim 1 or 2 wherein said pressing step comprises the steps of:

inserting an electro-graphitic carbon rod (51) having an outer diameter approximately equivalent to said inner diameter (53) of said bushing (23) into said bushing;
removing an amount of said electro-graphitic carbon rod (51) extending beyond said opposing ends;
drilling a first hole of a first diameter (41) through said electro-graphitic carbon rod (51) along a bushing centerline; and
reaming a second hole of a second diameter (43) in said electro-graphitic carbon rod (51) along said bushing centerline to form an electro -graphitic carbon liner/sleeve (11).

4. The method of claim 3 comprising the additional step of:

fabricating a chamfer (37) into at least one interior edge of said electro-graphitic carbon liner/sleeve (11).

5. The method of claim 4 wherein said fabricating step comprises fabricating a linear chamfer (37) extending at a chamfer angle (θ).

6. The method of claim 5 wherein said fabricating said linear chamfer (37) comprises fabricating said linear chamfer to a chamfer angle (θ) between 5° and 85°.

7. The method of claim 6 wherein said fabricating said linear chamfer (37) comprises fabricating said linear chamfer at a chamfer angle (θ) of approximately 45°.

8. The method of claim 3 comprising the additional step of fabricating a curve into at least one interior edge of said electro-graphitic carbon liner/sleeve (11).

9. The method of any preceding claim wherein said providing step comprises providing said bushing (23) comprising a titanium-based alloy.

10. A wear resistant bushing comprising:

a bushing (23) comprising an internal surface having an inner diameter (53) and opposing ends; and a graphite based liner/sleeve (11) pressed around said internal surface of said bushing (23).

11. The bushing of claim 10 wherein said bushing (23) is a turbine engine bushing.

12. The bushing of claim 10 or 11 wherein said graphite based liner/liner comprises electro-graphitic carbon.

13. The bushing of claim 12 wherein said electro -graphitic carbon liner/sleeve (11) comprises a chamfer (37) fabricating into at least one interior edge of said electro-graphitic carbon liner/sleeve (11).

14. The bushing of claim 13 wherein said chamfer (37) comprises a linear chamfer extending at a chamfer angle (θ).

15. The bushing of claim 14 wherein said chamfer angle (θ) is between 5° and 85°.

16. The bushing of claim 15 wherein said chamfer angle (θ) is approximately 45°.

17. The bushing of claim 12 or 13 comprising a curve fabricated into at least one interior edge of said electro-graphitic carbon liner/sleeve (11).

18. The bushing of any of claims 11 to 17 wherein said bushing comprises a titanium-based alloy.

19. A bushing assembly comprising:

a bushing (23) comprising an internal surface having an inner diameter (53) and opposing ends;
a trunnion (15); and
a graphite based liner/sleeve (11) pressed around said internal surface of said bushing in contact with said trunnion (15) and said bushing (23).

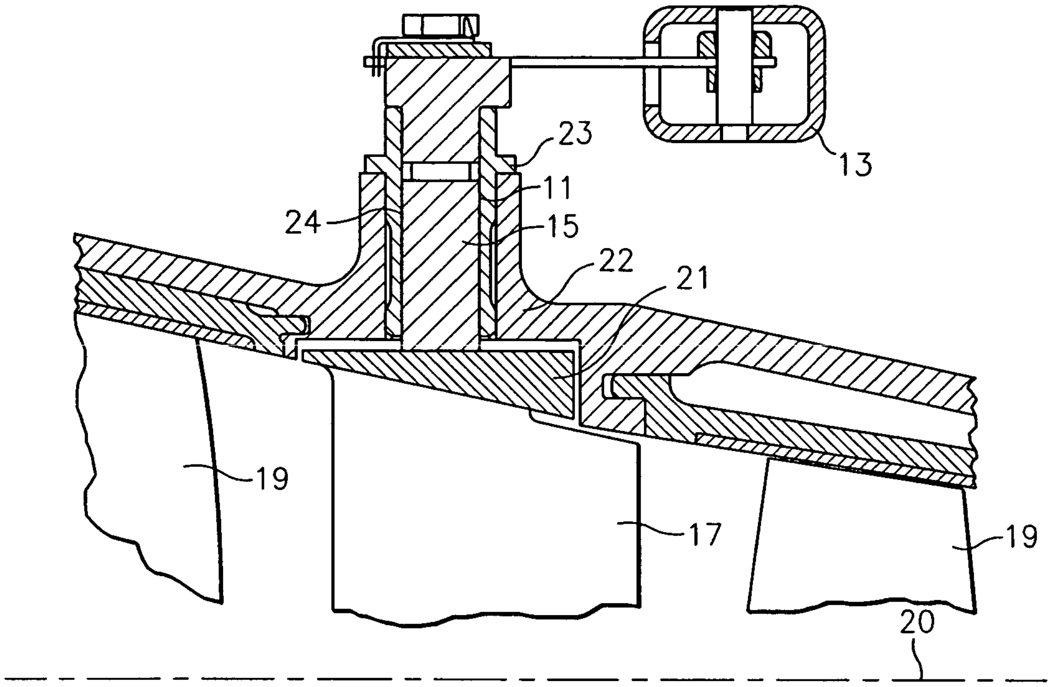

FIG. 1

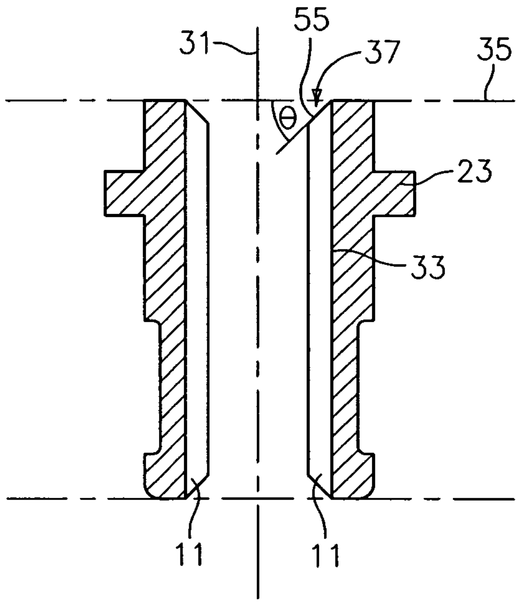

FIG. 2

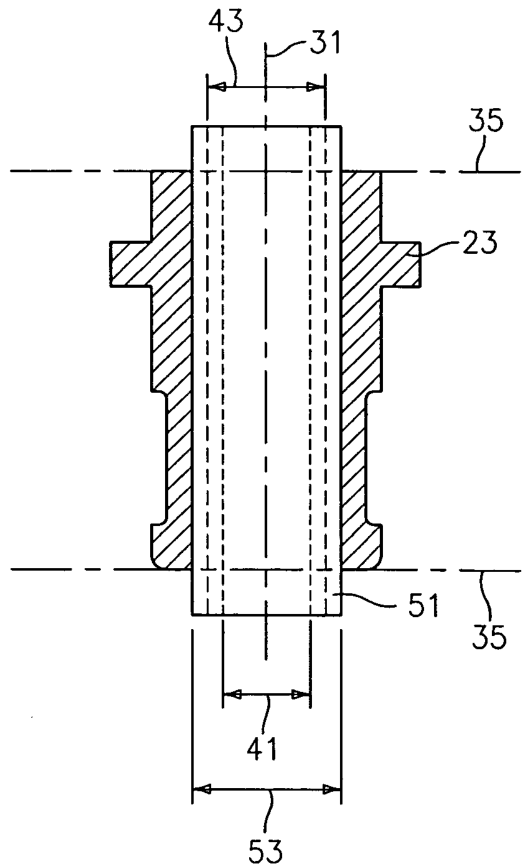

FIG. 3

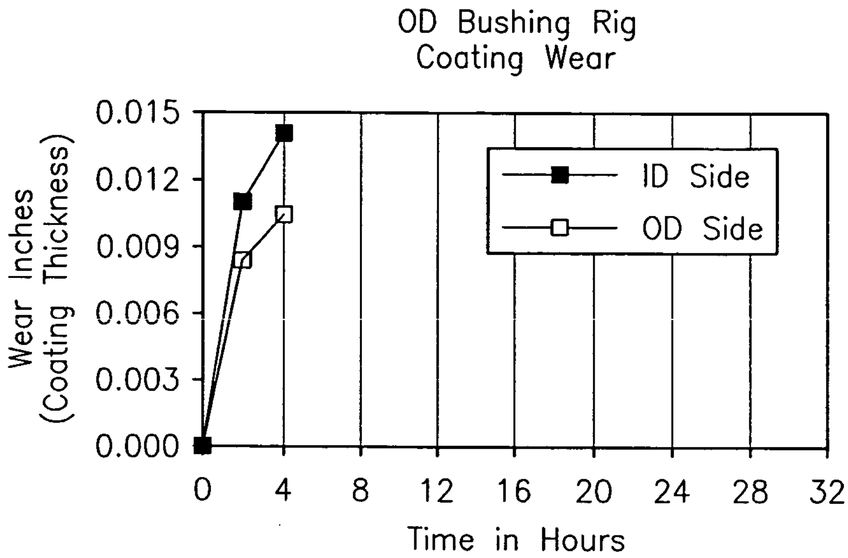
OD Bushing Rig
Coating Wear
Wear Inches
(Coating Thickness)
0.015
0.012
0.009
0.006
0.003
0.000
0
4
8
12
16
20
24
28
32
Time in Hours
ID Side
OD Side

FIG. 4a

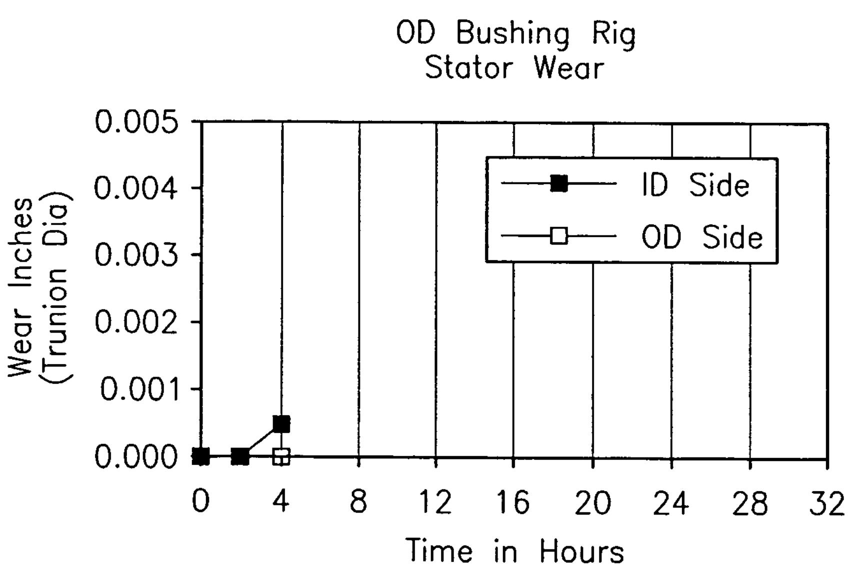
OD Bushing Rig
Stator Wear
Wear Inches
(Trunion Dia)
0.005
0.004
0.003
0.002
0.001
0.000
0
4
8
12
16
20
24
28
32
Time in Hours
ID Side
OD Side

FIG. 4b

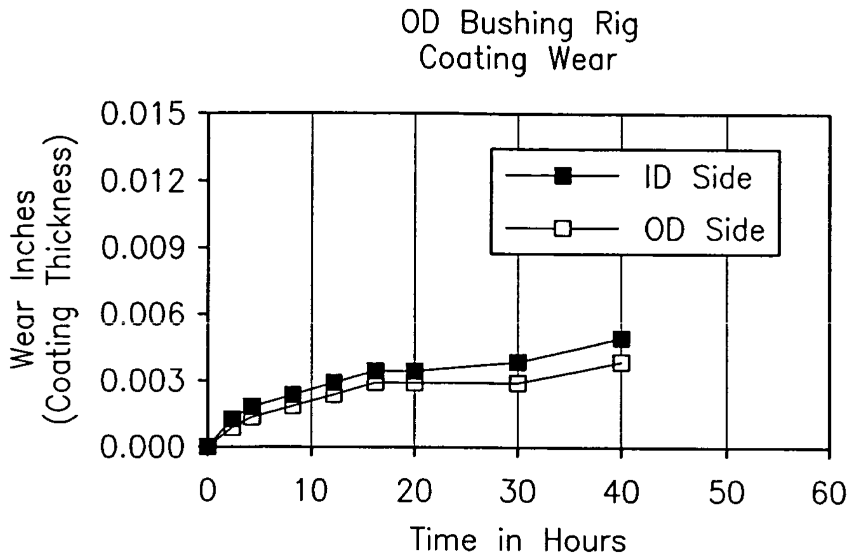
OD Bushing Rig
Coating Wear
Wear Inches
(Coating Thickness)
0.015
0.012
0.009
0.006
0.003
0.000
ID Side
OD Side
0
10
20
30
40
50
60
Time in Hours

FIG. 5a

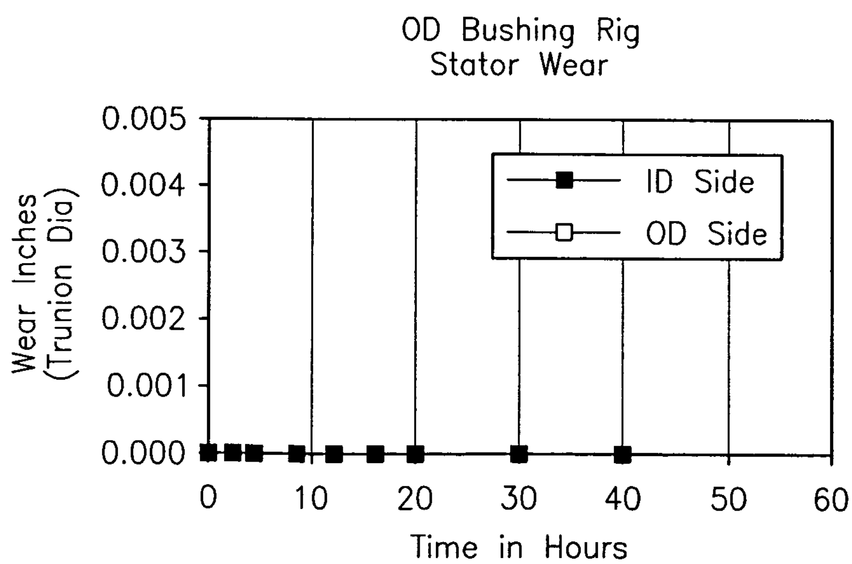
OD Bushing Rig
Stator Wear
Wear Inches
(Trunion Dia)
0.005
0.004
0.003
0.002
0.001
0.000
ID Side
OD Side
0
10
20
30
40
50
60
Time in Hours

FIG. 5b