CLAIMS

1. A cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer attached to one end of the shaft and a second end retainer attached on an opposite end of the shaft, the first end retainer having a fixed retainer with a pressure port therethrough and a movable piston portion with an outer surface subject to a local hydrostatic pressure, the movable piston portion comprising a floating retainer that slidably engages the fixed retainer such that a gap is defined between the fixed retainer and the floating retainer that is in fluid communication with the pressure port;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

such that the first rotary seal group is immersed in a lubricant that is in fluid communication with the port and fills the gap between the fixed retainer and the floating retainer such that the movable piston portion is configured to increase the pressure of the lubricant in response to an increase in the local hydrostatic pressure; and further

wherein the fixed retainer further comprises an annular channel and an outer perimeter, and further wherein the floating retainer comprises an annular wall that slidably engages the annular channel and an outer wall that slidably engages the outer perimeter of the fixed retainer.

2. The cutter assembly of claim 1, wherein the floating retainer further comprises a through port to facilitate injecting lubricant into the gap and a plug that sealingly closes the through port.

3. The cutter assembly of claim 1, wherein the cutter ring assembly comprises a hub rotatably mounted to the shaft with tapered roller bearings and a cutter ring extending radially outwardly from the hub.

4. The cutter assembly of claim 1, where the first rotary seal group comprises a duo-cone seal.

5. A cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer attached to one end of the shaft and a second end retainer attached on an opposite end of the shaft, the first end retainer having a movable piston portion with an outer surface subject to a local hydrostatic pressure;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first rotary seal group is immersed in a lubricant;

wherein the movable piston portion is configured to increase the pressure of the lubricant in response to an increase in the local hydrostatic pressure; and

wherein the first end retainer comprises an outer surface defining an annular channel with at least one pressure port that extends from the annular channel through the first end retainer to provide fluid communication with an inner side of the first rotary seal group, and an annular piston slidably disposed in the annular channel and exposed to the hydrostatic pressure, and further comprising means for retaining the annular piston in the annular channel, wherein the annular channel volume between the annular piston and the pressure port is filled with the lubricant.

6. The cutter assembly of claim 5, wherein the at least one pressure port comprises a plurality of pressure ports.

7. The cutter assembly of claim 5, further comprising a retaining element disposed in the annular channel and operable to retain the annular piston in the annular channel.

8. The cutter assembly of claim 5, wherein the first rotary seal group comprises a duo-cone seal.

9. A cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer attached to one end of the shaft and a second end retainer attached on an opposite end of the shaft, the first end retainer having a movable piston portion with an outer surface subject to a local hydrostatic pressure;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first rotary seal group is immersed in a lubricant;

wherein the movable piston portion is configured to increase the pressure of the lubricant in response to an increase in the local hydrostatic pressure; and

wherein the first end retainer comprises a plurality of cylindrical recesses defined in an outer surface of the first end retainer, and a plurality of pressure ports extending from a corresponding one of the plurality of cylindrical recesses to the first rotary seal group, and a plurality of pistons slidably disposed in a corresponding one of the plurality of cylindrical recesses, wherein the pistons are exposed to the hydrostatic pressure.

10. The cutter assembly of claim 9, further comprising a plurality of extendable seals, wherein each extendable seal is attached near an outer edge of a corresponding one of the plurality of cylindrical recesses.

11. A pressure-compensated cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer non-rotatably attached to one end of the shaft and a second end retainer non-rotatably attached to an opposite end of the shaft;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first and second rotary seal groups are enclosed within a closed volume defined by the shaft, the cutter ring assembly, and the first and second end retainers, and further wherein the closed volume is otherwise filled with a lubricant; and

wherein the first end retainer includes a movable portion having an outer surface that is exposed to an ambient pressure and an inner surface exposed to the lubricant such that the movable portion will increase the pressure of the lubricant in response to an increase in the ambient pressure;

wherein the first end retainer comprises a fixed retainer having at least one pressure port that is in fluid communication with the lubricant, and the movable portion comprises a floating

retainer that slidably engages the fixed retainer such that a gap is defined between the fixed retainer and the floating retainer, wherein the gap is filled with the lubricant; and

wherein the fixed retainer further comprises an annular channel and an outer perimeter, and further wherein the floating retainer comprises an annular wall that slidably engages the annular channel and an outer wall that slidably engages the outer perimeter of the fixed retainer.

12. The pressure-compensated cutter assembly of claim 11, wherein the floating retainer further comprises at least one through port to facilitate injecting lubricant into the gap.

13. The pressure-compensated cutter assembly of claim 11, wherein the cutter ring assembly comprises a hub rotatably mounted to the shaft with tapered roller bearings and a cutter ring extending radially outwardly from the hub.

14. The pressure-compensated cutter assembly of claim 11, wherein the first rotary seal group comprises a duo-cone seal.

15. A pressure-compensated cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer non-rotatably attached to one end of the shaft and a second end retainer non-rotatably attached to an opposite end of the shaft;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first and second rotary seal groups are enclosed within a closed volume defined by the shaft, the cutter ring assembly, and the first and second end retainers, and further wherein the closed volume is otherwise filled with a lubricant;

wherein the first end retainer includes a movable portion having an outer surface that is exposed to an ambient pressure and an inner surface exposed to the lubricant such that the movable portion will increase the pressure of the lubricant in response to an increase in the ambient pressure;

wherein the first end retainer comprises a fixed retainer having at least one pressure port that is in fluid communication with the lubricant, and the movable portion comprises a floating

retainer that slidably engages the fixed retainer such that a gap is defined between the fixed retainer and the floating retainer, wherein the gap is filed with the lubricant; and

wherein the first end retainer comprises an outer surface defining an annular channel with at least one pressure port that extends from the annular channel through the first end retainer and is in fluid communication with the first rotary seal group, and an annular piston slidably disposed in the annular channel and exposed to the ambient pressure, and further comprising means for retaining the annular piston in the annular channel.

16. The pressure-compensated cutter assembly of claim 15, wherein the at least one pressure port comprises a plurality of pressure ports.

17. The pressure-compensated cutter assembly of claim 15, wherein the at least one pressure port and the portion of the annular channel disposed inwardly of the annular piston are filled with the lubricant.

18. The pressure-compensated cutter assembly of claim 15, further comprising a retaining element disposed in the annular channel and operable to retain the annular piston in the annular channel.

19. A pressure-compensated cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer non-rotatably attached to one end of the shaft and a second end retainer non-rotatably attached to an opposite end of the shaft;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first and second rotary seal groups are enclosed within a closed volume defined by the shaft, the cutter ring assembly, and the first and second end retainers, and further wherein the closed volume is otherwise filled with a lubricant; and

wherein the first end retainer includes a movable portion having an outer surface that is exposed to an ambient pressure and an inner surface exposed to the lubricant such that the movable portion will increase the pressure of the lubricant in response to an increase in the ambient pressure;

wherein the first end retainer comprises a plurality of cylindrical recesses defined in an outer surface of the first end retainer, and a plurality of pressure ports extending from a corresponding one of the plurality of cylindrical recesses to the first rotary seal group, and a plurality of pistons slidably disposed in a corresponding one of the plurality of cylindrical recesses, wherein the plurality of pistons are exposed to the ambient pressure.

20. The pressure-compensated cutter assembly of claim 19, further comprising a plurality of extendable seals, wherein each extendable seal is attached near an outer edge of a corresponding one of the plurality of cylindrical recesses.

~~CLAIMS~~

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer attached to one end of the shaft and a second end retainer attached on an opposite end of the shaft, the first end retainer having a movable piston portion with an outer surface subject to a local hydrostatic pressure;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first rotary seal group is immersed in a lubricant; and

wherein the movable piston portion is configured to increase the pressure of the lubricant in response to an increase in the ~~ambient~~ local hydrostatic pressure, such that the pressure differential across the first and second rotary seal groups remains small.

2. The cutter assembly of Claim 1, wherein the first end retainer comprises:

a fixed retainer having at least one pressure port therethrough that is in fluid communication with the lubricant; and

the movable piston portion of the first end retainer comprises a floating retainer that slidably engages the fixed retainer such that a gap is defined between the fixed retainer and the floating retainer that is in fluid communication with the at least one pressure port, and wherein the gap is also filed with the lubricant.

3. The cutter assembly of Claim 2, wherein the fixed retainer further comprises an annular channel and an outer perimeter, and further wherein the floating retainer comprises an annular wall that slidably engages the annular channel and an outer wall that slidably engages the outer perimeter of the fixed retainer.

4. The cutter assembly of Claim 2, wherein the floating retainer further comprises a through port to facilitate injecting lubricant into the gap and a plug that sealingly closes the through port.

5. The cutter assembly of Claim 2, wherein the cutter ring assembly comprises a hub rotatably mounted to the shaft with tapered roller bearings and a cutter ring extending radially outwardly from the hub.

6. The cutter assembly of Claim 2, where the first rotary seal group comprises a duo-cone seal.

7. The cutter assembly of Claim 1, wherein the first end retainer comprises an outer surface defining an annular channel with at least one pressure port that extends from the annular channel through the first end retainer to provide fluid communication with an inner side of the first rotary seal group, and an annular piston slidably disposed in the annular channel and exposed to the hydrostatic pressure, wherein the annular channel volume between the annular piston and the pressure port is filled with the lubricant.

8. The cutter assembly of Claim 7, wherein the at least one pressure port comprises a plurality of pressure ports.

9. The cutter assembly of Claim 7, further comprising a retaining element disposed in the annular channel and operable to retain the annular piston in the annular channel.

10. The cutter assembly of Claim 7, wherein the first rotary seal group comprises a duo-cone seal.

11. The cutter assembly of Claim 1, wherein the first end retainer comprises:

a plurality of cylindrical recesses defined in an outer surface of the first end retainer, and a plurality of pressure ports extending from a corresponding one of the plurality of cylindrical recesses to the first rotary seal group, and a plurality of pistons slidably disposed in a corresponding one of the plurality of cylindrical recesses, wherein the pistons are exposed to the hydrostatic pressure.

12. The cutter assembly of Claim 11, further comprising a plurality of extendable seals, wherein each extendable seal is attached near an outer edge of a corresponding one of the plurality of cylindrical recesses.

13. A pressure-compensated cutter assembly for a tunnel boring machine comprising:

a shaft;

a cutter ring assembly rotatably mounted on the shaft;

a first end retainer non-rotatably attached to one end of the shaft and a second end retainer non-rotatably attached to an opposite end of the shaft;

a first rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the first end retainer; and

a second rotary seal group having a first portion engaging the cutter ring assembly and a second portion engaging the second end retainer;

wherein the first and second rotary seal groups are enclosed within a closed volume defined by the shaft, the cutter ring assembly, and the first and second end retainers, and further wherein the closed volume is otherwise filled with a lubricant; and

wherein the first end retainer includes a movable portion having an outer surface that is exposed to an ambient pressure and an inner surface exposed to the lubricant such that the movable portion will increase the pressure of the lubricant in response to an increase in the ambient pressure, such that the pressure differential across the first and second rotary seal groups remains small.

14. The pressure-compensated cutter assembly of Claim 13, wherein the first end retainer comprises a fixed retainer having at least one pressure port that is in fluid communication with the lubricant, and the movable portion comprises a floating retainer that slidably engages the fixed retainer such that a gap is defined between the fixed retainer and the floating retainer, wherein the gap is filed with the lubricant.

15. The pressure-compensated cutter assembly of Claim 14, wherein the fixed retainer further comprises an annular channel and an outer perimeter, and further wherein the floating retainer comprises an annular wall that slidably engages the annular channel and an outer wall that slidably engages the outer perimeter of the fixed retainer.

16. The pressure-compensated cutter assembly of Claim 14, wherein the floating retainer further comprises at least one through port to facilitate injecting lubricant into the gap.

17. The pressure-compensated cutter assembly of Claim 14, wherein the cutter ring assembly comprises a hub rotatably mounted to the shaft with tapered roller bearings and a cutter ring extending radially outwardly from the hub.

18. The pressure-compensated cutter assembly of Claim 14, wherein the first rotary seal group comprises a duo-cone seal.

19. The pressure-compensated cutter assembly of Claim 14, wherein the first end retainer comprises an outer surface defining an annular channel with at least one pressure port that extends from the annular channel through the first end retainer and is in fluid communication with the first rotary seal group, and an annular piston slidably disposed in the annular channel and exposed to the ambient pressure.

20. The pressure-compensated cutter assembly of Claim 19, wherein the at least one pressure port comprises a plurality of pressure ports.

21. The pressure-compensated cutter assembly of Claim 19, wherein the at least one pressure port and the portion of the annular channel disposed inwardly of the annular piston are filled with the lubricant.

22. The pressure-compensated cutter assembly of Claim 19, further comprising a retaining element disposed in the annular channel and operable to retain the annular piston in the annular channel.

23. The pressure-compensated cutter assembly of Claim 13, wherein the first end retainer comprises a plurality of cylindrical recesses defined in an outer surface of the first end retainer, and a plurality of pressure ports extending from a corresponding one of the plurality of cylindrical recesses to the first rotary seal group, and a plurality of pistons slidably disposed in a corresponding one of the plurality of cylindrical recesses, wherein the plurality of pistons are exposed to the ambient pressure.

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24. The pressure-compensated cutter assembly of Claim 23, further comprising a plurality of extendable seals, wherein each extendable seal is attached near an outer edge of a corresponding one of the plurality of cylindrical recesses.

25. A pressure-compensated cutter assembly comprising:

a shaft;

a cutter ring assembly rotatably engaging the shaft;

a first end retainer and a second end retainer both non-rotatably engaging the shaft;

a first seal group disposed in an enclosed volume in the cutter assembly and configured to provide a seal between the cutter ring assembly and the first end retainer; and

a second seal group disposed in an enclosed volume in the cutter assembly and configured to provide a seal between the cutter ring assembly and the second end retainer;

wherein the enclosed volume is filled with a lubricant, and at least one of the first and second end retainers includes a piston means configured to increase a pressure of the lubricant in response to an increase in an ambient hydrostatic pressure, such that the pressure differential across the first and second seal groups remains small.

AMENDED SHEET(ART. 34)