

DLC-COATED GATE VALVE IN PETROLEUM PRODUCTION OR WATER INJECTION

Field of the invention

- 5 The present invention relates to gate valves. More specifically, the invention relates to gate valves used in petroleum production systems such as Xmas trees connected to petroleum production wells and water injection wells.

Background of the invention and prior art

- 10 Gate valves used for control of petroleum production are operated at high pressure and temperature. The well shut in pressure can be above 103,5 MPa, the contact pressure between valve parts is even higher, whilst the temperature can be above 177 °C. In operation the valve can be in one position for long periods of time, such as in position open for petroleum production. According to
15 standards, such as Norsok, the function of the valve is to be tested periodically, such as every third month.

- Unfortunately the valves have an inherent friction problem. More specifically, the valve parts have a tendency of sticking, adhering or cold welding to each other,
20 resulting in high friction. This is also termed stick slipping and galling. In order to overcome the friction problem, the actuators, umbilicals and other associated equipment must be dimensioned in order to operate the valve in a state of enhanced friction. Accordingly, actuators, umbilicals and other associated equipment, in addition to the valve itself or parts thereof, must be up to several
25 times larger, stronger or expensive than required compared to the friction level at its lowest.

- An approach that has been used for some time in order to overcome the problems is to apply coating on sealing faces of the valve. More specifically,
30 coating of tungsten carbide is used. Currently, coating of tungsten carbide on surfaces subject to sliding is an industry standard for gate valves for control of petroleum production, particularly subsea petroleum production control valves. Despite the tungsten carbide coating, the sticking together of valve parts is still a severe problem. The effect of the sticking or friction problem is not only enhanced

friction but also stick slipping or uneven movement of the valve gate during operation as compared to a smooth, even, continuous movement.

Friction tests reveal that the friction problem should have been solved by the coatings according to the industry standard. However, practical experience reveal
5 that the friction sometimes increases to an enhanced level over time, from a lower start up level of friction, which is very surprising in view of the friction test results. Even though the friction problem has been encountered for many years, it has not yet been possible to mitigate.

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US 20070163655 A1 describes a gate valve for use with well fluids, where the surfaces meant to slide against each other are coated with a hard carbide surface and a top layer of diamond like carbon (DLC). This document does not describe embodiments where the valve is used on subsea production equipment.

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Neither does the document mention the importance of hydrogen in the DLC.

US 2004118455 A1 also describes a valve where carbide and DLC are used on the sliding surfaces.

20 Luo, S.Y. et al. : "A study of the water behavior of diamond like carbon films under the dry reciprocating sliding contact", Wear, 2001, vol. 249, pp. 800-807, describes that the coefficient of friction between surfaces treated with DLC and other surfaces, are reduced when the surfaces has passed through a certain number of sliding cycles.

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The inventors have investigated the problem in depth in order to find further details on the problem, including when the problem occur and finding a solution to overcome the problem if possible. More specifically, the investigations revealed that larger surfaces appear sometimes to behave very different with
30 respect to friction than smaller samples typically used for testing, even though the surfaces and coatings are identical, a large scale problem sometimes occur. More specifically, the investigations revealed that a severe friction problem can occur in a full scale real gate valve even though testing on smaller samples do not indicate any problem. This is surprising since the test procedures have been

determined by experts in the field. Furthermore, valve fluid without oil contents, such as dry gas or water without oil, are found to enhance the problem in general, resulting in increased friction over time. Eventually, highly polished
5 surfaces seem to increase the problem with respect to the unexpected size effect and the unexpected fluid type effect.

When the friction problem occurs, it will in general increase with time or operation cycles in a real full scale gate valve. The problem is still not quantified in great
10 detail and the mechanisms resulting in the problems are not yet understood in great detail. But in addition to what is mentioned above the problems have been found to in general increase with increasing level of friction, increasing sliding distance, increasing contact pressure, increasing temperature, and particularly, the problems increase with time or operation cycles. The prevailing mode of
15 friction is probably a dry or mixed type of friction. The problem is found to be very relevant for gate valves, particularly subsea gate valves, presumably due to large sealing surfaces, high pressures and long sliding distance.

The objective of the present invention is to reduce or eliminate the friction
20 problem discussed above.

These objectives are obtained by a gate valve according to claim 1, a method of commissioning or operating a gate valve according to claim 5, and use of a diamond like carbon (DLC) top layer according to claim 8. Additional preferred
25 embodiments are claimed in the dependent claims.

Summary of the invention

To this end, one aspect of the invention provides a gate valve for control of
30 petroleum production or water injection, distinctive in that at least one surface subject to sliding in operation of the valve comprises a top layer coating of diamond like carbon (DLC). The DLC-coating comprises sp³ bonds or a combination of sp² and sp³ bonds, characterised in that the DLC-coating comprises hydrogen.

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The solution of the invention solves or mitigates the above mentioned problems.

This is very surprising since persons of ordinary skill in the art would have no

particular guidance as to when the problems occur or how to solve them, since test procedures using smaller samples do not reveal the problem or give indications to a solution.

- 5 The valve can comprise several surfaces with top layer coating of DLC, such as the surfaces of a valve seat ring on either side of a gate member for sliding operation, as well as the gate. The valve may comprise other coatings, at other locations or as sub-layers of coating below a DLC coating top layer. The valve may comprise a DLC top layer coating on one or both facing surfaces subject to
- 10 sliding, preferably one surface as this provides sufficient technical effect of the coating as revealed by full scale testing. Preferably at least one of the following surfaces subject to sliding is coated: the seat surfaces facing the gate and the gate surfaces facing the seat. However, any additional metal object surfaces subject to movement, as well as static surfaces, can be coated with a DLC top
- 15 layer coating. Most preferably, at least one of all interfacing metal object sealing surfaces comprises a DLC top layer coating.

- DLC coatings consist of a mix of sp³ and sp² bonds, and it can also contain other elements as metal or hydrogen. DLC coatings with most sp³ bindings,
- 20 typical 75% sp³ and above is called tetrahedral amorphous carbon (ta-C). DLC coatings with a mix of sp³ and sp² bindings are called amorphous carbon (a-C). If hydrogen is mixed into this coating, called hydrogenated amorphous carbon (a-C:H). If hydrogen is mixed into a ta-C it is called hydrogenated tetrahedral amorphous carbon (ta-C:H).

Full scale testing has revealed that the type of DLC coating is critical. The valve is tested to simulate real life conditions. This includes operation of the valve at both elevated temperatures and with both gas and fluid as pressure medium in the valve. Typical differential pressure in the valve during operating is 69 MPa, but could be as high as 138 MPa. A typical gas used for testing is nitrogen.

In nitrogen or other dry inert gasses the inventors found out that DLC containing hydrogen has a clear benefit over DLC coatings without any hydrogen, especially a-C:H DLC with a hydrogen content of 17 atom-% or more.

In a preferred embodiment the DLC-coating is applied on top of a carbide-coating or a chrome nitride coating. Preferably the DLC-coating has been applied by PVD (physical vapour deposition) , PACVD (plasma assisted chemical vapour deposition) or CVD (chemical vapour deposition); alternatively other application methods known in the art for DLC coating application, directly on metal objects or on sub coatings, can be used. There are several suppliers that can apply DLC coating, such as Oerlikon Balzer of Lichtenstein and DIARC of Finland.

According to one aspect of the invention, a method of commissioning or operating a gate valve according to any of above embodiments is provided. During commissioning or assembly, the at least one surface with a DLC top layer coating subject to sliding in operation of the valve is operated or treated to a point beyond a top of high initial friction according to a curve of friction coefficient against sliding distance or close-open cycles in operation.

According to another aspect of the invention, use of a diamond like carbon (DLC) top layer coating comprising hydrogen is provided. Preferably more than 16 atom-% hydrogen and most preferred more than 17 atom-% hydrogen, on at least one surface subject to sliding in operation of a gate valve for control of petroleum production or water injection is provided.

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The invention provides use of a diamond like carbon (DLC) top layer coating on at least one surface subject to sliding in operation of a gate valve for control of petroleum production or water injection. Preferably, the use is

- 5 for a subsea petroleum production or water injection Xmas tree gate valve, for coating at least one of all interfacing sliding and sealing surfaces.

Figures

- The invention will be further explained in the following detailed description with
10 reference to the drawings, of which:

Figure 1 illustrates an embodiment of a gate valve according to the invention, with surfaces coated by DLC;

- 15 Figure 2 illustrates the underlying problem of the invention;

Figure 3 illustrates the underlying problem and the technical effect of the invention;

Figure 4 illustrates the coefficient of friction (COF) as a function of the number of cycles for different DLC-coatings, at room temperature and water as pressure medium; and

Figure 5 illustrates COF as a function of the number of cycles for different DLC-coatings, at elevated temperature and nitrogen as pressure medium.

Detailed description

Reference is made to Figure 1, illustrating a gate valve 1 of the invention in open and closed position, respectively. The valve comprises a valve body 2, a gate 3 and two valve seats 4 and 5 respectively, the valve seats are arranged on either side of the gate 3 inside the valve body. The valve body, seats and gate includes a flow bore 6, the gate is connected to an actuator 7, the actuator can slide the gate so that the flow bore is open or closed. As the person skilled in the art easily will recognize, a typical gate valve is illustrated. For clarity, only one of the identical reference numerals for valve parts have been included for open and closed position illustrations. Preferably at least one of the following surfaces subject to sliding is coated: the seat surfaces 8 and 9 facing the gate and the gate surfaces 10 and 11 facing the seat. However, any additional metal object surfaces subject to movement, as well as static surfaces, can be coated with a DLC top layer coating. Most preferably, at least one of all interfacing metal object sealing surfaces comprises a DLC top layer coating. In a preferable embodiment, the seats comprise a DLC top layer coating both on the surfaces facing the gate and the opposite surfaces away from the gate.

Reference is made to Figure 2, illustrating the coefficient of friction COF versus linear sliding distance test cycles at a contact pressure of 210 MPa at ambient test room temperature and no lubrication. The test is a small scale laboratory test. The data are for samples having tungsten carbide coating versus tungsten carbide coating as well as DLC top layer coating versus tungsten carbide coating. The tungsten carbide coatings were identical and according to industry standard

for production tree or water injection tree gate valves. The curves reveal that the sample data are similar but the samples including one test object with a DLC top layer coating had a lower friction, at about 50% compared to tungsten carbide versus tungsten carbide. The curves increase slightly and at a similar or
5 approximately identical relative rate. The data gives no indication to the person of ordinary skill in the art that a DLC top layer coating for a full scale real gate valve would give a dramatically different result.

Reference is made to Figure 3, illustrating the results of a full scale gate valve
10 test with no lubrication and water at 69 MPa as the valve pressure medium resulting in a contact pressure between the sliding surfaces of 210 MPa. Tungsten carbide versus tungsten carbide coating resulted in a start friction about three times higher than having a top layer coating according to the invention, which is surprising from the smaller difference in friction from the
15 friction sample tests. However, the huge difference is that the valve with DLC top coating has a coefficient of friction COF below 0,1 after more than 500 open close cycles whilst the industry standard gate valve with tungsten carbide versus tungsten carbide coating was stopped after only 7 open close cycles due to rapidly increasing COF, as apparent from the curves. The invention provides a
20 gate valve with a permanent very low friction level compared to industry standard valves, also after some time in service, without severe problems with pure water or dry gas service.

Reference is made to Figure 4, illustrating the results of three full scale gate
25 valve tests with no lubrication and water at 69 MPa as the valve pressure medium resulting in a contact pressure between the sliding surfaces of 210 MPa. The figure show the results from one coating without hydrogen and two coatings with hydrogen according to the invention sliding against a tungsten carbide gate. All of these coatings have a low stable friction compared to the tungsten carbide
30 vs tungsten carbide solution in Figure 3.

Reference is made to Figure 5, illustrating the results of three full scale gate valve tests with no lubrication, elevated temperature to 135 °C and nitrogen gas at 69 MPa as the valve pressure medium resulting in a contact pressure between

the sliding surfaces of 210 MPa. In these tests the different DLC coated seats has been sliding against a tungsten carbide coated gate. In this environment the hydrogenated DLC coating performs surprisingly better than the non-hydrogenated DLC. After 15 cycles the non-hydrogenated DLC test was aborted due to high friction. The DLC test with 17 atom-% hydrogen was stopped after 28 cycles, still having a COF 40% lower than the non-hydrogenated DLC.

The valve of the invention may comprise any feature as here described or illustrated, in any operative combination, and any such operative combination is an embodiment of the invention. The method of the invention may comprise any feature or step as here described or illustrated, in any operative combination, and any such operative combination is an embodiment of the invention. The use of the invention may comprise any feature or step as here described or illustrated, in any operative combination, and any such operative combination is an embodiment of the invention.

Claims:

1.

Gate valve for control of petroleum production or water injection, at least one surface subject to sliding in operation of the valve comprises a top layer coating of diamond like carbon (DLC), said DLC-coating comprises sp³ bonds or a combination of sp² and sp³ bonds, characterised in that the DLC-coating comprises more than 16 atom-% hydrogen.

2.

Valve according to claim 1, characterised in that the DLC-coating comprises 17 atom-% or more hydrogen.

3.

Valve according to claim 1 or 2, characterised in that the valve is a subsea petroleum production or subsea water injection Xmas tree gate valve.

4.

Valve according to any one of the preceding claims, characterised in that said coating is applied on top of a carbide-coating or a chrome nitride coating.

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Method of commissioning or operating a gate valve according to any one of claims 1-4, characterised in that during commissioning or assembly, the at least one surface with a DLC top layer coating subject to sliding in operation of the valve is operated or treated to a point beyond a top of high initial friction according to a curve of friction coefficient against sliding distance or close-open cycles in operation.

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6.

Method according to claim 5, characterised in that the commissioning of the valve comprises undertaking open-close cycles.

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7.

Method according to claim 5,

c h a r a c t e r i s e d i n that the commissioning of the valve comprises

5 polishing of valve parts before assembly.

8.

Use of a diamond like carbon (DLC) top layer coating comprising more than 16

atom-% hydrogen on at least one surface subject to sliding in operation of a gate

10 valve for control of petroleum production or water injection.

9.

Use according to claim 8, wherein the DLC top layer coating comprises more than 17 atom-% hydrogen.

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10.

Use according to claim 8 or 9, for a subsea petroleum production or subsea water injection Xmas tree gate valve, for coating at least one of the interfacing sliding and sealing surfaces.

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11. Use of a DLC according to claim 8 or 9, where the DLC has a-C:H structure.

12. Use of DLC according to clam 8 or 9, where the DLC has ta-C:H structure.

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