Investigation of various pipe materials for riser operation in the arctic seas

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Abstract. A riser, which is an offshore water separation column is the main difference between offshore drilling and onshore drilling. The idea of the research is to calculate the stressed-deformed state of a riser made of various materials to identify technological advantages during drilling on the shelf and at sea in the Arctic. The article is the result of research conducted in the Mathematica application program to determine the operating stresses that depend on the drilling process conditions and the external environment. Modern drilling technologies are designed to increase the capacity of the equipment or to use alternative materials. Given the pace of development of the fields of the Northern Shelf of Russia, there is a need to explore the use of alternative materials for such marine equipment as risers. Keywords: riser, shelf, Arctic, drilling technologies, aluminum pipes, drill string, steel pipes, offshore fields.

1 Introduction

The experience of using high-strength aluminum alloys for the production of drill pipes in the oil and gas industry has shown their significant advantages over steel. One of the main advantages of aluminum pipes is a low specific weight and a higher specific strength. Specific strength is of particular importance in modern conditions, when there is an increasing need to develop new deposits located at greater depths of the sea and in difficult meteorological conditions.

2 Methods

One of the key features of offshore field development facilities is the use of the riser in the process of drilling and producing hydrocarbons. The design of the riser depends on the technological parameters and the environmental conditions of the place where it will be use. The riser is exposed to loads from the marine environment, such as hydrodynamic loads from waves and currents and the movements of a drilling ship.

Since ensuring the reliability of the riser is an important component of the successful development of offshore fields, there are very high requirements for risers. The use of international experience in the design of the riser block is not justified due to the regional location differences and the specifics of the Russian climate. The main problem is to prevent
the possibility of brittle destruction, because it is a sudden and uncontrolled process. The occurrence of cracks can be caused by the contact of the riser with the ice formation, for example, during the season when ice formation occurs [1,2].

The strength calculation of the drilling riser made of aluminum alloy is an urgent task in drilling. The calculation will increase the use of aluminum in the oil and gas industry and increase the maximum load of equipment reduce the likelihood of accidents. The justification of the possibility of using aluminum alloys for the production of the riser, as well as the justification of the operating conditions of such equipment in the development of oil and gas fields are important tasks of modern design. [3,4].

3 Results

Steel 30 and aluminum alloy D16T were selected for the research. Next, we calculated the stressed-deformed state of the riser made of various materials in order to identify technological advantages in the process of drilling wells. The article is the result of research conducted in the Mathematica application program to determine the operating stresses that depend on the drilling process conditions and the external environment.

The first step was to calculate the riser deflection in the disconnected state. A similar situation occurs in the event of an accident on a drilling vessel or an unexpected stop of the riser tension system. The calculation results represented in Figure 1.

Figure 1 shows that the riser deflection of the aluminum alloy and steel riser is a sinusoidal curve, due to the lack of oscillatory motion compensation of the drilling vessel.

It can also be noted that the maximum total riser deflection stress at various vertical deviation reach the maximum values in the lower part of the sea. The aluminum riser experiences almost two times less stress from the deflection of the riser, due to the greater ductility of the material in comparison with steel. The maximum riser deflection stress occur at a depth of 320 m, and their value is slightly more than 400 MPa.

Figure 1 shows that the riser, made of aluminum alloy D16T, meets the strength conditions with a margin of about 10 % in an emergency condition. The steel riser does not meet the strength conditions, exceeding the safety margin by about 15 %.

The next step was to calculate the riser deflection in the connected state when drilling does not occur. The results represent in Figure 2.

Figure 2 shows that the riser deflection is different in appearance from the curves of the riser deflection in an emergency, which affects the operation of the riser tension system. The riser deflection does not exceed 30 meters at the average speed of the underwater current,
varying from 0 to 0.8 m/sec. It is also seen that the oscillatory motion of the drilling vessel and the undercurrents cause irregular deflection of the riser along the entire depth from the sea surface to the bottom.

It can also be concluded that the maximum riser deflection stress of a steel riser are at the sea surface, and their value is slightly less than 600 MPa. For an aluminum riser, the maximum riser deflection stress is almost three times less - 205 MPa.

**Fig. 2.** Results of the calculation of the riser deflection without drilling.

As follows from the diagram of the statical strength ratio of the aluminum riser in Figure 2, the static strength margin is almost 10 % in the connected state in when drilling does not occur. The strength conditions of the riser will be met even under the conditions that the average speed of the sea current is not higher than 0.9 m/sec and the oscillatory motion of the drilling vessel is not more than 10°. It is obvious that the steel riser does not meet the strength conditions because it exceeds the static strength margin by a value of more than 50%.

The next step was to calculate the riser deflection in the drilling mode. When calculating the deflection of the riser in the drilling mode, in addition to external forces, it is necessary to take into account the forces and moments of forces of the hydrodynamic fluid pressure in the drill string and in the annular space. Therefore, the force from the hydrodynamic pressure in the annular space is assumed equal for the riser and for the drill string.

**Fig. 3.** Pressure inside the drill string and in the annular space.
According to the Barlow formula, the maximum pressure that the riser pipe made of steel and aluminum alloy can withstand was found. The results of the calculations are shown in Table 1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum internal pressures, MPa</th>
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<tbody>
<tr>
<td>Steel 30</td>
<td>35</td>
</tr>
<tr>
<td>Aluminum alloy D16T</td>
<td>36</td>
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</table>

Table 1. Maximum internal pressures.

The next step was to calculate the impact force of a floating ice formation weighing 310 tons at a speed of 1 m/sec. The deflection of the riser, which is formed after the collision with the ice, is represented in Figure 4.

Figure 4 shows that the maximum deflection of the riser occurs on the sea surface. This means that the impact of the ice formation on the undisturbed riser does not lead to significant deflection deformations of the riser and its departure from the drilling point.

Also, Figure 4 shows the maximum riser deflection stress when it collides with an ice object. It follows that the riser deflection stress due to the impact is much less than the stress due to the motion compensation of the drilling vessel. Thus, normal stresses from the impact do not cause a critical stress state in the riser.

The statical strength ratio is also represented in Figure 4. The graph shows that statical strength ratio is very small and therefore floating ice floes cannot destroy the riser.

4 Discussion

Calculation in the event of an accident on a drilling vessel or an unexpected stop of the riser tension system shows that the riser, made of aluminum alloy D16T, meets the strength conditions with a margin of about 10% in an emergency condition. The steel riser does not meet the strength conditions, exceeding the safety margin by about 15%, under the same metrological conditions. In addition, the aluminum riser experiences almost two times less riser deflection stress, due to the greater ductility of the material in comparison with steel. The maximum riser deflection stress occur at a depth of 320 m, and their value is slightly more than 400 MPa.

The calculation when riser in the connected state and drilling does not occur showed that can maximum riser deflection stress of a steel riser are at the sea surface, and their value is slightly less than 600 MPa. For an aluminum riser, the maximum riser deflection stress is
almost three times less - 205 MPa. The strength conditions of the riser will be met even under the conditions that the average speed of the sea current is not higher than 0.9 m/sec and the oscillatory motion of the drilling vessel is not more than 10°.

5 Conclusion

During the drilling process, the maximum pressure acting on the riser occurs at the bottom of the sea, which does not exceed the maximum permissible values.

The calculation, when the riser collides with the ice formation, showed that the total riser deflection stress does not exceed the limit stresses and the safety margin for impact loads is almost 98 %. The impact of the ice formation on the undisturbed riser does not lead to significant riser deflection and its departure from the drilling point.

References


