RISER COLUMN STABILITY CONCERNS FOR DEEP-WATER AND ULTRA-DEEP-WATER DRILLING

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Abstract: *This paper proposes an analysis over the operational conditions encountered during drilling operations. The analysis refers to those factors which are impacting the riser column stability during operations. The results of these factors over the riser column are called riser mechanics. Thus, the objective of the work analyse to which extent the riser column fulfils the applicable API recommendations in force and obtaining theoretical results in this regard for drilling in deep waters. These results constitute the starting point in the simulation with the help of specialized software and getting useful results over optimal risers operations in deep water drilling conditions.*

1. Riser mechanics – overview

The riser column is a complex construction aimed to ensure the connection between the well head and the drilling unit. The functions of this assembly are complex and are not limited only to ensure the space necessary for cuttings removal from the well. As the water depth increases, the working conditions of this assembly becomes challenging due to the complex forces and extreme environmental conditions which are impacting the operational mode as well as the stability. In this paper several aspects concerning riser mechanics and the behaviour of the riser column will be evaluated against different operational situations.

2. The design of the riser column and the selection criteria

The optimal configuration of the riser column plays an important with regards to the operational parameters. The dynamic characteristic of the drilling unit are taken in to consideration since the design phase of the riser column being an important parameter during this stage and the riser column should fulfil these minimum conditions:

- The riser column should cope to the design forces which may affect the stability but also integrity during the drilling process
- Regardless the normal operational conditions, the riser column should be able to fulfil also designed emergency situations
- Fatigue elements and the extreme loads which can occur are design elements which have to be taken in to account during the design phase

An important aspect which has to be taken in to consideration during this design stage is the determination of the optimal weight of the riser column in the water. As a matter of fact, the correct assessment of the buoyancy elements and correct positioning of those can ensure an optimal stability of the riser column. A neutral position can be obtained in order to achieve a reduction of the top tension as this is important for the tensioning system. However, there is a down side in this scenario: the lower tension can increase and this will result in overloading the well head [3].

The riser column can be considered a tube with high thickness walls which is impacted by different type of loads (e.g. shear forces, compression etc.)

The forces acting over the riser column can be evaluated by using von Mises & Tresca relations and the result have to comply with acceptable limits of the materials composing the riser column.

Moreover, the requirements for the top and lower tension must be verified in order to ensure the riser column stability for all operational phases, emergency situations included. As first step in this direction should include stability verification of the riser column towards limit conditions which may comprise of:

- Maximum water depth
- Maximum mud density
- Environmental conditions in connected mode

Moving forward, if the first condition has been fulfilled, the vertical deviation of the riser column must checked against requirements as well as fulfilling safety operational conditions, regardless the factors which may affect this. The API 2RD recommends a structural and dynamic analysis of the riser column if is considered that the operational environment impose further risk increase. Special simulations will be completed with a dedicated software, usually installed onboard the drilling units, in order to evaluate the vertical deviations of the riser column.

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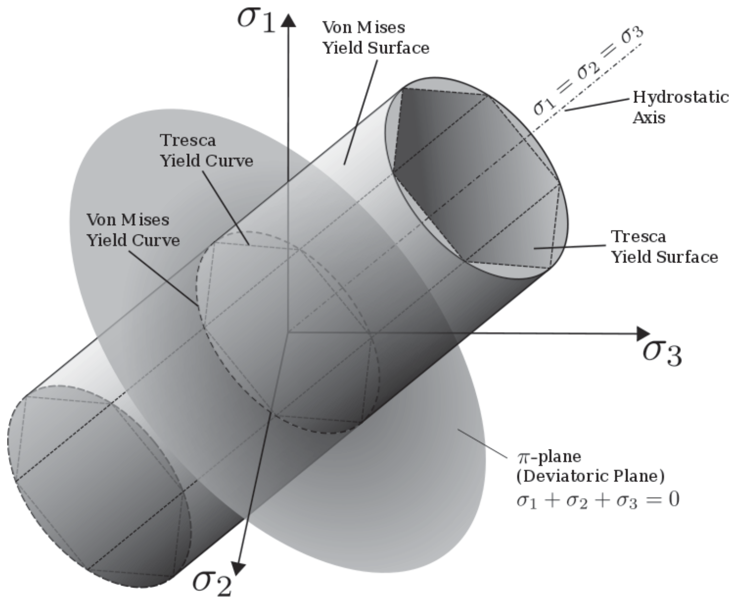

Fig.1. *von Mises & Tresca applied for a riser section [4]*

3. Main forces which influence the stability of the riser column

The riser column can be represented as a beam connected at both ends with a spherical articulation. The various axis movement of the drilling platform are compensated by dedicated equipment (telescopic riser, upper flex joint and tensioner ring) in order to maintain the drilling unit on the position. The linear weight of the riser is the difference between the linear weights of the joint in water minus the linear thrust exerted through the thrust collar by the buoyancy elements that are dressing it. The internal pressure generated locally by the mud column is equal to the mud specific gravity multiplied by the local column height. The external pressure generated locally by the sea water is equal to the sea water specific gravity multiplied by the local water depth. It has to be noted that what acts against the walls of the riser joints is the local difference in between the above two terms [2].

In the usual case of a riser string full of mud, the higher the mud weight & the water depth, the higher the differential pressure on the bottom that tends to “inflate” the joints generating hoop stress.

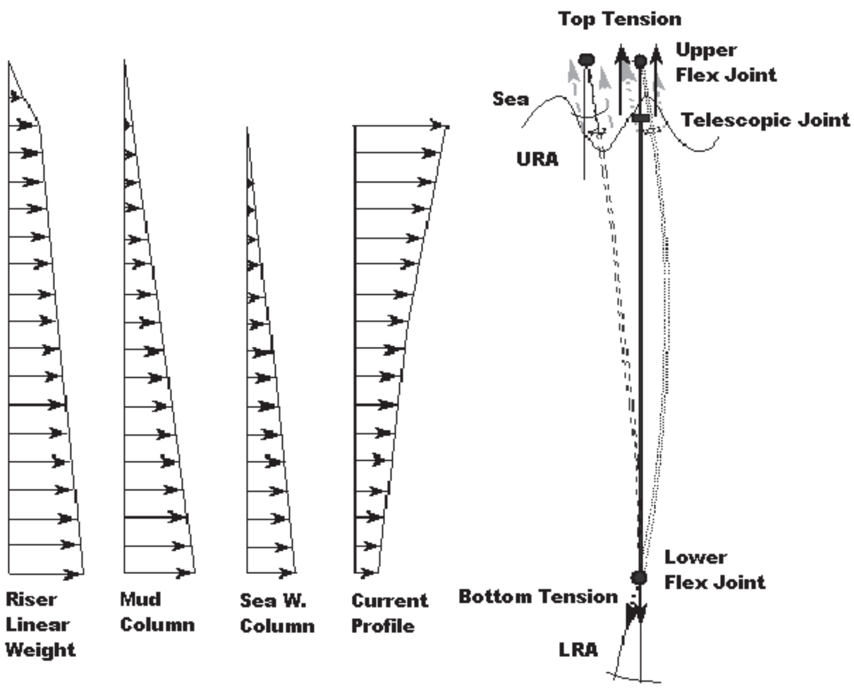

Fig.2. *The action of different forces over the riser column*

Should the riser for any reason be partially empty (mud heavy losses due to weak down hole formation), the riser wall would be subject to the external pressure only in the void zone.

The hydrodynamic forces of the waves will impact the riser column on the upper part and this is evaluated with MOJS equations (Morison, O'Brien, Johnson and Schaaf) [2]. The resistance of the riser column in to the water due to the oscillations is proportional with:

- A drag coefficient (friction, wake and added mass).
- The density of the sea water.
- The cross section of the riser string.

This approach is valid only if the current value is up to two knots. If this value is exceeded, the vortex phenomenon occurs, which generate vibrations in combination with the wave movement. The transversal vibrations are depending on the value of the tensions which are propagating along the riser column.

If those conditions are exceeding the acceptable operational limitations the tensioning system can be affected with consequences over the integrity of composed elements. A preventive measure is to reduce the top tension for a short period of time awaiting the normal operational parameters to be reinstalled.

However, the values exceeding two knots are not normal and therefore the solution of reducing the top tension for a short period of time can be adopted but such solution can overload the well head and may result in a fatigue rupture, as aforementioned, hence this measure should be correctly assessed.

In order to exemplify those forces we can imagine that a wave with a speed of two knots can generate a tension of 60-70 tones within the tensioning system for a water depth of 1 500 meters. Assuming a top tension of 350 tones and a lower flex joint tension of 150 tones an angle of 7 degrees deviation from vertical can be expected. Under these circumstances the acceptable operational limits are exceeded and the drilling process is suspended. The values mentioned are valid as long the top and lower tension values are not modified. The angle is modifying up to 3 degrees if the values mentioned are modified [1].

Another possibility to reduce the wave or currents influence is to modify the positioning of the drilling unit but keeping under control the lower angle of the riser column. The resulted position is meant to keep under control all parameters which may impact the vertical positioning of the riser column which is in fact the mission of the riser management system.

According with aforementioned it is obvious that old methods for keeping the drilling unit on position no long apply. Nowadays, it's unthinkable to run drilling operations in deep waters without the support of an advanced raiser management system which automatically adjust all operational parameters in order to maintain the integrity of the riser column as well as safety of the drilling operations. If the well head can be considered somehow rigid with regards to the BOP this no longer apply. Depending on the soil characteristics as well as the quality of the cement job for the upper section of the well, the BOP can oscillate with a range between 0-2 degrees during drilling operations which may cause damages to the drilling equipment as well as increasing the cyclic loads over the well head which will end up with the final fatigue rupture.

The design length of the raiser column is influenced by the environmental conditions by means of the horizontal movement of the drilling unit but also is related with the stroke of the telescopic joint [3].

During the design stage of the riser column for a given location, the worst case scenario has to be taken in to consideration. Also it is recommended to reduce as much as possible the lower flex joint angle trough the positioning system of the drilling unit. Any uncontrolled movement generated by the environmental conditions can generate additional stress over the riser column and finally will impact the well head which can be exposed for early fatigue rupture. Due to the fact that the lower and upper flex joint are not design to absorb the axial movement of the drilling unit these tensions, somehow will impact the tensioning ring and finally ,these excessive loads, will impact the tensioning system as well.

Finally, the best way to manage efficiently the riser column, is to keep the positioning of the drilling unit under control within the operational parameters established before starting the drilling program and especially design for a given location with an adequate top tension and this is the big challenge.

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