EVALUATION OF WELLHEAD LOADS AND TENSIONS USING FEM FOR DEEP WATER DRILLING WELLS

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Abstract: *This paper aims an analysis of a complex situation over the well head for an offshore well with regards to the loads and stress impacting this equipment. The analysis is highlighting the effects of the daily operations over the well head along with the loads envelope supported. Those situations described are meant to verify the relevant API requirements but also an analysis is performed with regards to those emergency situations which may encounter during operations such as drive off and drift off. The objective of this paper is to evaluate the required time allowable for drilling operations until the well head may be the subject of a fatigue rupture and to propose improvement solutions in order to prolong the operational life of the equipment.*

1. Evaluation of the fatigue rupture possibility of the well head

As the water depth increases the possibility of a fatigue rupture of the chances to encounter a well head rupture are more likely. Therefore, it is recommended that before starting the deep water operations, this possibility needs to be assessed since the beginning of the well design process.

The increased length of the riser column as well as the environmental factors specific for the operational location (waves, currents etc.) are influencing the stability of the riser column by inducing a specific movement in to the string and creating the conditions for the possibility of an early fatigue rupture of the well head. Taking in to considerations all these factors can be concluded that once the fatigue limit exceeded, the final rupture can occurs at any time.

For a normal well head the cyclic loads will highlight the manufacturing faults (normally the welded zone is the most exposed one). Once the critical zone is reaching the critical limits the final fatigue rupture will be initiated. In figure 1 are presented the most critical areas for a generic well head.

The well head is impacted by variable loads caused mainly by the environmental factors. One factor which has to be taken in to account is the relative movement of the drilling unit on the horizontal. In this case, if the tensioning system is not properly adjusted, may have an impact over the riser column and then this can cause additional tensions over the well head. Depending of the amplitude and the intensity of these loads, the well head is exposed to early fatigue rupture as is represented in figure 2.

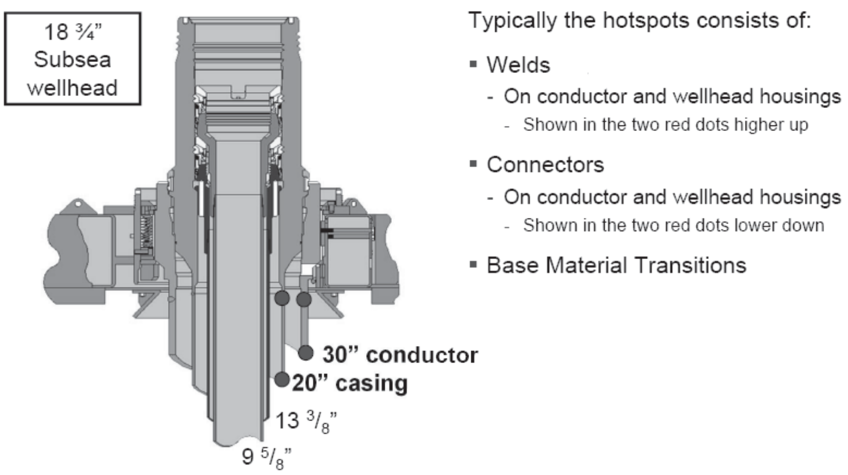

Fig. 1 **Well head hotspots**

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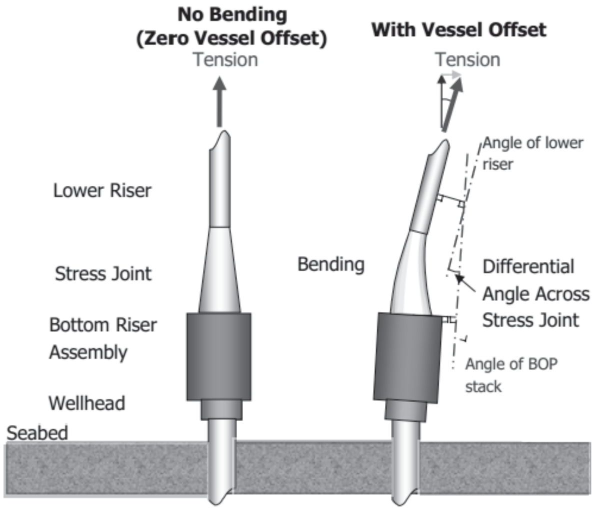

Fig. 2 **Load regime of the well head**

As aforementioned, the early fatigue rupture of the well head is caused by excessive loads caused by the drilling unit movement as well as the action of the environmental factors over the raiser column. Therefore, a particular aspect of this issue is represented by the mechanical characteristics of the well head material. Actually, the fatigue occurs during normal drilling operations but the purpose of this paper is to highlight those factors which are amplifying this process leading to an early fatigue rupture. One of the functions of the well head is to provide stability of the BOP but this is in strict correlation with the soil characteristics as well as the quality of the cementing job for the first section of the well.

One of the most important characteristics of the soil is stiffness and the most usual method for establishing this is to apply P-Y curves. These are normally used to determine the foundation characteristics in civil engineering. In order to determine the P-Y curves, the following standards can be used:

- ISO 19901:4;
- ISO 19902;
- API RP 2A.

These standards show different methods for P-Y curves calculations depending on soil characteristics.

With regards to the fatigue resistance, this can be categorized as following:

- Small fatigue resistance, when the well head can take less than 10^5 cycles
- Increased fatigue resistance, when the well head can take more than 10^5 cycles

The first case refers to a structure placed in the plastic deformation domain while the second case is suitable for the elastic domain. According with this analysis and due to the operational requirements the ideal case would be to have the well head placed in the second case.

2. The loads regime of the drilling unit

A marine drilling system is the subject of different loads and forces which are impacting the well head in terms of cyclic loads accumulation and those can be summarized as following (see also figure 3):

Environmental data:

- Water depth
- Wind
- Marine currents
- Waves

Design characteristics of the drilling unit

- Response of the drilling unit during waves and wind impact
- Marine currents response
- RAO curves (*Response Amplitude Operator*)

Riser column

- Diameter
- Wall thickness
- The weight of the riser column
- Tensioning system
- Dynamic and riser mechanics

Mooring lines (as applicable)

- Mechanical properties
- Tension values of the lines

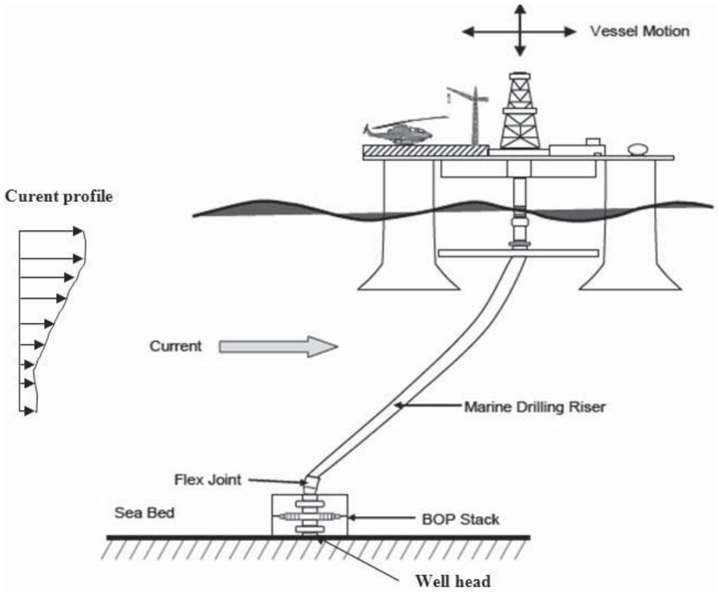

Fig.3 **General overview of the main factors impacting the drilling unit stability**

3. Simplified method for determination of the operational days

The exact determination of number of operational days for the well head cannot be determined exactly due to multiple factors involved. However, a simplified method has been presented which is evaluating few main parameters and based on that an approximation can be made. Anyhow, the method presented in the biography section can provide an indication with regards to the performance or not of the subsea system. After the completion of the analysis, compensating measures can be taken in order to improve the system. The acceptance criteria defined is based on the concept of "standard BOP days" and the reference was set for 365 days in operation. If result of the analysis is exceeding this number, then compensation measures are to be taken. Anyhow, compensating measures can be taken in any case in order to improve the system performance as log those are economical viable. [1]

This method is using as input data basic the basic characteristics of the drilling system such as: the height of the BOP stack, over pull at LMRP connector and bending stiffness of lower flex joint.

The method described above has been applied to a real drilling system in order to evaluate the performance of a given drilling system configuration. The result was not in accordance with acceptable criteria and, consequentially, compensating measures were proposed as following:

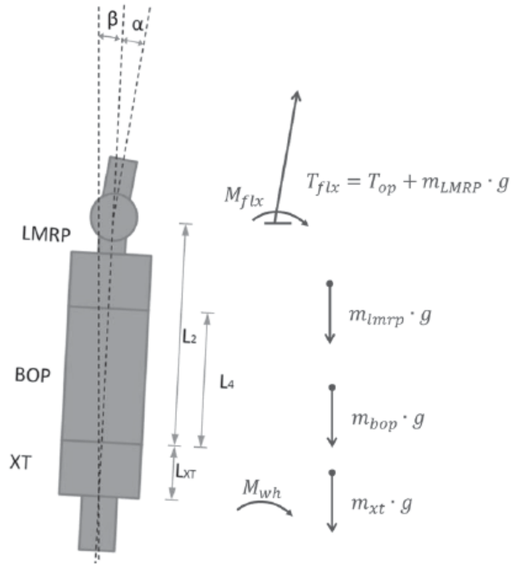

Fig.4 **The loads of the BOP stack [1]**

1. The BOP weight to be reduced by using suspension cables connected to the platform. There is a down side of this approach and is that the cables needs to be connected together with a compensating system which needs to be synchronized in order to reduce additional stress in to the BOP stack.
2. Remove one annular preventer from the BOP configuration. This measure proves to be feasible and is reducing not only the weight of the BOP but also the height.

It was proven an increase of 50 % of the performance of the system after taking the compensating measures.

In addition, in order to verify the theoretical data obtained an analysis was completed by using a software solution based on FEM method.

4. Static and dynamic study of the well head

The study was completed using Solid Works software in order to create the stress diagrams in accordance with theoretical result obtained above. For this analysis the von Mises criterion was used. From constructive point of view, the well head is presented in figure 5.

A 3D model of the well head was design (figure 6) which represents the mesh structure of the object.

The scope of this structure is to split the object in order to allow mathematical modeling of the structure and finally the mechanical simulation to be completed.

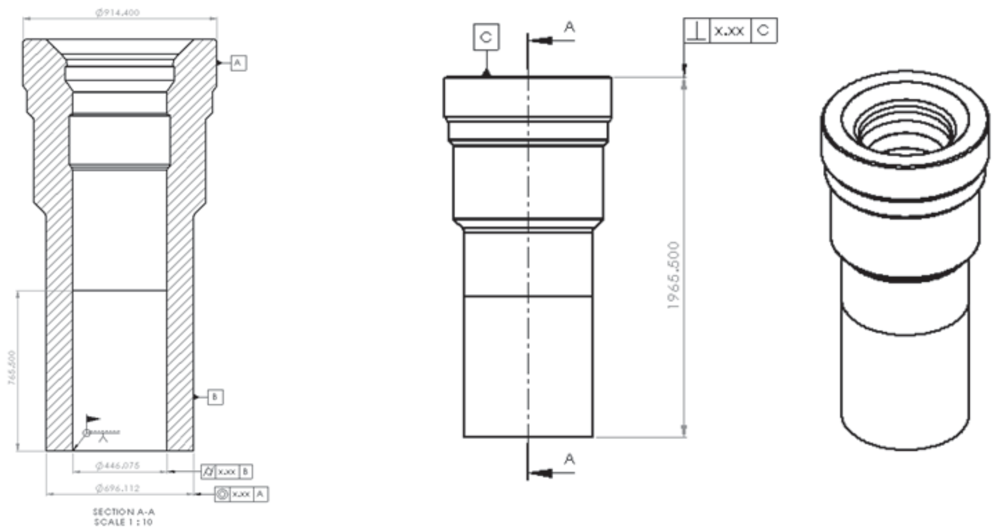

Fig. 5 **Well head, general overview**

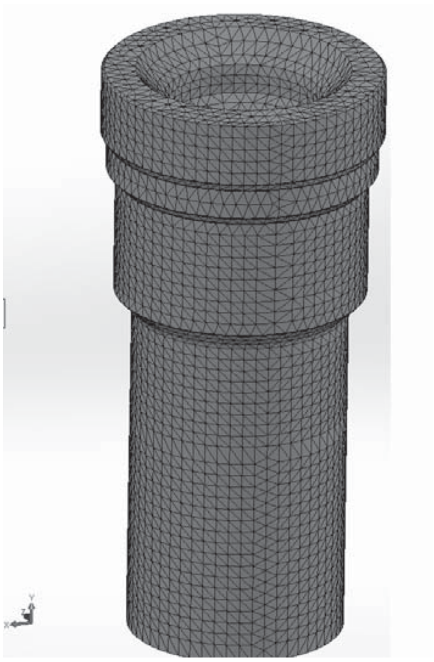

Fig.6 **FEM – mesh structure of the well head**

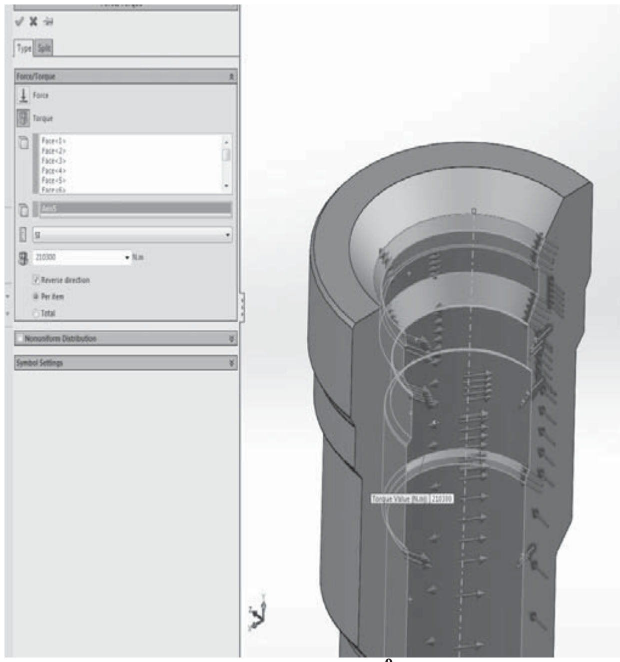

Fig.7 **Torque moment for 1^0 angle**

In the figure 7 is represented the torque moment (app. 210 kNm) transmitted over the inner surface of the object for an inclination angle of 1 degrees.

Figure 8 represents the diagram of specific elastic deformations (tangential) oriented by the X axis in Cartesian system for an angle of 1 degree. These tensions are produced in the support area of the BOP stack. Also, the symmetry between the opposite values of elastically deformations is given by the torsion and bending moments. Therefore, the blue area is influenced by the compression and the red one is under elongation impact.

In figure 9 is represented the diagram of specific elastic deformations following the Y axis of the Cartesian system. Precisely, at the basis (in the weld zone) the fibre of the material is the subject of elongation. This is generated by the bushing pressure in to the inner side which is corresponding to a rigid domain of the deformation system.

Also in the upper part (blue) on the outside area a compression of the material fibre is produced due to the inclination angle.

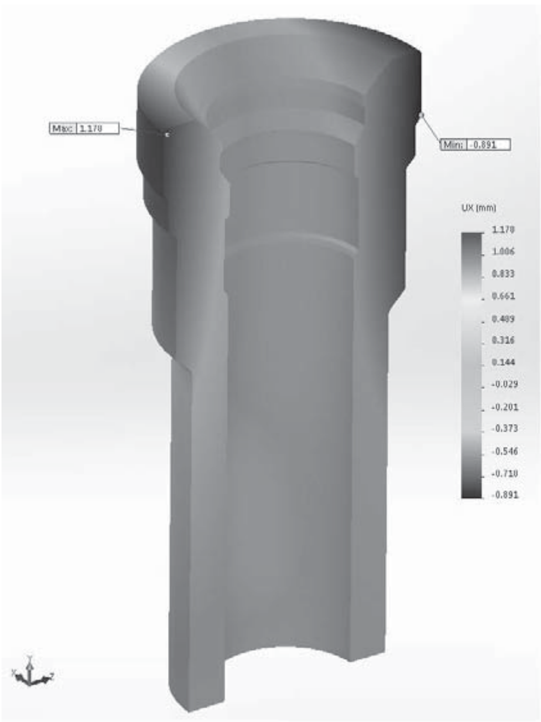

Fig.8 **Diagram of elastic tangential deformation on X axis for 1^0 angle**

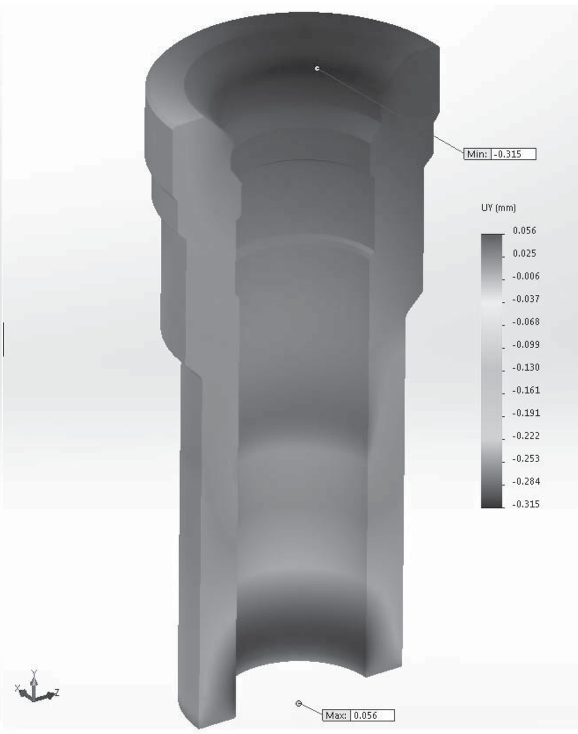

Fig. 9 **The diagram of the elastic deformation for the Y axis for 1^0 angle**

Figure 10 is representing the diagram of specific deformation (tangential) following the Z axis of the Cartesian system.

Like the case of the X axis, symmetrical elastically deformations is produced which can be observed in the picture. This picture also highlights the section with the elongation caused by the torsion and bending moments.

The compression would have been produced in the opposite side.

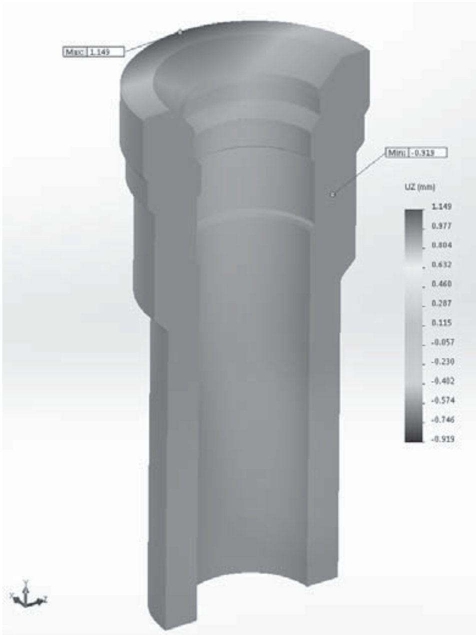

Fig.10 **The diagram of the tangential elastical deformations following Z axis for 1^0 angle**

References

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2. *** * ***
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