THE EVALUATION OF THE OILFIELD EQUIPMENT`S CAPABILITY BY TECHNICAL INSPECTION, USING THE DYNAMIC ANALYSIS

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Abstract: The dynamic loads, often occurring in the case of drilling rigs, lead to the most dangerous stress for these equipments, involving their life time reducing and, also, their premature wear. In order to evaluate and reduce the damage risks of the drilling rigs, taking into account the real dynamic loads is strongly recommended. The technical expertises point out the equipment's damages that occur during their functioning. The authors make obvious that the methods used until now can show only partially the really behaviour of the drilling rigs. Using the dynamic analysis during technical inspections, their real life time, load-bearing capacity and reinforcement measures can be established, in order to increase the analyzed equipments` capability and durability.

1. GENERAL CONSIDERATIONS

A metallic structure (mast, metallic derrick) is a slender metallic construction, made of straight bars (rolled shapes) with welded ends, which has many issues regarding its stability not yet solved. These issues relate to the study in terms of dynamic stability and are consistent with recent research showing that only study in terms of static stability behaviour is not enough. Thus, studying the stability of metallic structures submitted to dynamic loads, as the masts or metallic derricks from oilfield industry are, should also include the dynamic stability problems.

The studies made in this paper are the result of current trends manifested in the construction of oilfield equipment: technical expertise, extending oilfield equipment's life and upgrades (increasing the technical characteristics) of the existing oilfield equipment, wherever is possible.

The specific dynamic loads of the drilling/intervention rigs (both on-shore and off-shore) produce the most dangerous stress and lead to their premature wear, reducing their life time.

In order to decrease the failure risk assessment of these resistance structures is imperative to take into account the real dynamic loads. Hence, is necessary to develop a general algorithm for dynamic analysis, by dynamic calculus, using the finite element method which results can be applied in real time during the technical expertise, and verified by experimental measurements with modern devices, on the real structures.

Technical expertise is insistently required by beneficiaries, because many drilling rigs have accumulated a long service time, showing many structural damages. In the present, many of the technical expertise have made only visual findings or non-destructive measurements on the wall thickness and on the metallic elements` wear (ultrasonic methods and penetrating liquids/magnetic particles measurements).

Thus, a performant dynamic algorithm, supplemented by direct measurements in real time, in the frequency domain, is a rigorous, fast and efficient method for detecting any structural defects. On this basis, during the technical expertise, the remaining life time and the actual load-bearing (load-carrying) capacity can be determined. Also, measures to enhance the examined structure's capacity and durability can be immediately taken.

2. THE PRINCIPLE OF THE DYNAMIC ANALYSIS METHOD USED DURING TECHNICAL EXPERTISE

The dynamic phenomena produce the most dangerous real loads for the drilling/ intervention rigs (mobile or stationary, on-shore or off-shore). Among the identified dynamic loads, relevant for the technical expertise, they can include:

- drill pipe pulled out from elevator;
- drill pipe stuck in elevator;
- stress caused by engine torque, given by the rotary swivel (Top Drive).

In this paper, the algorithms for the dynamic analysis, using these types of significant loads, for a metallic structure (in this case, the dynamic mast TD 320-43R which fits Romanian drilling rigs), are presented.
The calculations to be presented here have the following characteristics: are rigorously tested by scientific methods; are real-time methods that can be applied quickly on demand; are based on computer algorithms that can be easily applied in working conditions.
Due to extreme operating conditions during the drilling process, a dynamic energy exchange occurs, which is critical for the structural calculus of a drilling/intervention rig.
During the technical expertise, the following types of dynamic analysis can be performed:

- the calculus of the free mode shapes and of the natural frequencies for the resistance structures;
- the structure’s response in time through direct dynamic analysis;
- the structure’s response in time through modal dynamic analysis;
- the frequency response through direct dynamic analysis;
- the frequency response through modal dynamic analysis;
- the PSD analysis (Power Spectral Density) for random response;
- the Spectral Response engendering analysis.

3. NEW SOLUTIONS TO MORDENIZE DRILLING/INTERVENTION RIGS

In the recent decades, the drill string’s trip was realized using the square kelly. With the exception of minor improvements, the rotary table, the square kelly and the square drive master bushings have remained unchanged, also the main drill string’s trip operations. The recent years emphasis on off-shore drilling, on directional drilling and on deep drilling imposed the finding of new technical solutions, better adapted to these requirements and capable to lead to the time reducing of drilling the borehole.
In the spirit of what was said above, one has acted in two main directions. On one side were refined (by adopting new structural solutions) the systems used for the drill string’s trip, and on the other hand more efficient systems for the drill pipe stand’s mechanized trip have been developed.
The main novelty regarding the drill string’s rotation and downhole advance was the Top Drive, which can support the drill string, thus giving up the rotary table and the square kelly. Differences from one system to another consist in the character of the driving (electric, diesel, hydraulic) and in a several constructive details, all of them being materialized into a certain level of performance. Driving at the drill string’s top has many advantages.
In figure 1, it is presented the Top Drive TDS 11- SA, manufactured by National Oilwell Varco, used on one Romanian off-shore drilling platforms. Adapted to the dynamic mast TD 320-43R, this system transmits the engine torque directly to the drill string. The reactive moment is transmitted to the metallic structure using the Top Drive’s guideway girder connected to the front C of the dynamic mast. The main particularity of this driving system is that the reactive moment twists the dynamic mast from about 35 m height to

4,60 m (against the floor), meaning about a triple drill pipe stand of 27 m. In figure 2, the unloading girder connected to the dynamic mast TD 320-43R is presented. The inferior part of the connection is made at 4,60 m against the floor. However, the presence of the Top Drive to heights about 35 m from the floor induces the danger of the vibrations and shocks transmission to the dynamic mast TD 320-43R.

Figure 1.Top Drive TDS 11 SA.

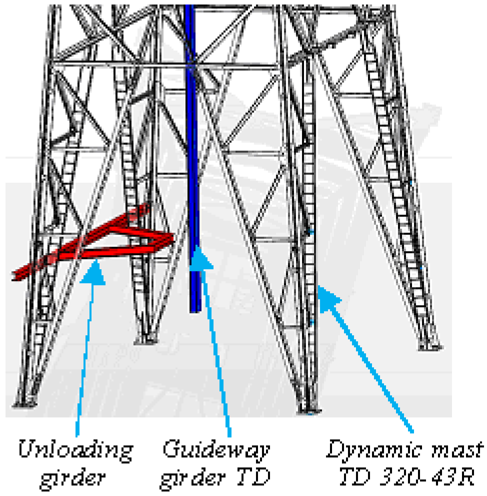

Figure 2. Schematic of the unloading and guideway girders.

In order to make the dynamic analysis of the mast TD 320-43R, the finite element method will be used.

The dynamic model will take into account the influence of damping, so the damping will be introduced for each vibration mode. The damping coefficient is defined in correspondence with each vibration mode by:

$$\xi_i = \frac{C_i}{C_{critic}} \tag{1}$$

The dynamic response of the mast TD 320-43R will be obtained using the modal analysis and the frequencies analysis method.

4. THE DYNAMIC RESPONSES

a). When the drill pipe is pulled out from elevator:

The variation of the hook load (when drill pipe is pulled out from elevator) is presented in figure 3 and it is studied for a drill pipe stand's trip ([2], [5]), and the dynamic response for the node with a maximum displacement is presented in figure 4.

To determine this dynamic response, we utilized the same damping coefficient $\xi = 0{,}05$ for all the structure's nodes. Then, in order to determine the dynamic response under the given loads, we utilized the dynamic coefficient, which has the value, for the node 557 (with the maximum displacement; the node 557 is on the crown block):

$$c_d = \frac{\Delta_{din}}{\Delta_{static,total}} = \frac{2{,}81e^{-2}}{2{,}35e^{-2}} = 1{,}195 \quad (2).$$

The displacement's value $(\Delta_{static})_{total} = 2{,}35e^{-2} m$ was determined making the static calculus for the hook load's value corresponding to the drill string's weight, to which is added the functioning moment from the Top Drive.

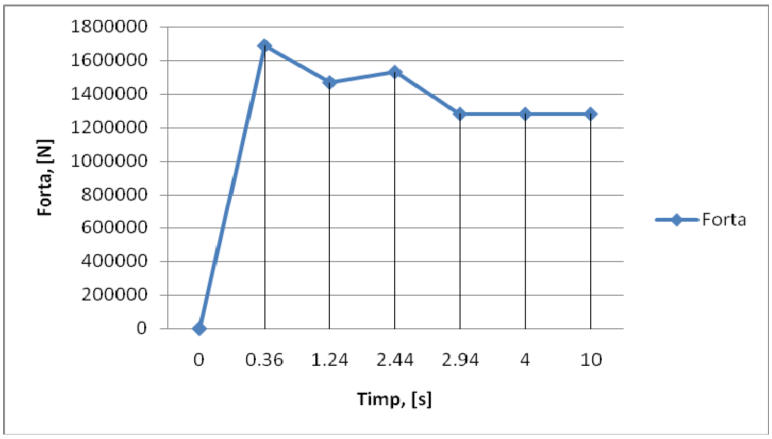

Figure 3. The variation of the hook load during the pulling out from elevator

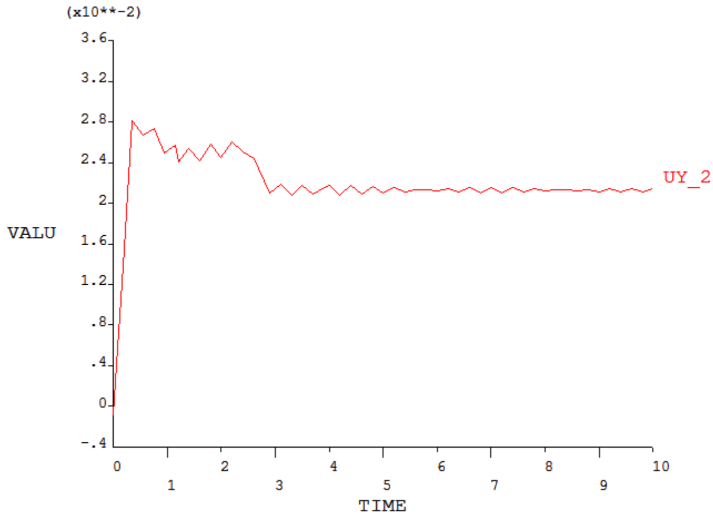

Figure 4. The dynamic response for the node 557

b). When the drill pipe is stuck in elevator:

The hook load's variation (for the case when the drill pipe is stuck in elevator) is presented in figure 5 and it is studied for a drill pipe stand's trip ([2], [5], [6]), and the dynamic response for the node 557 is presented in figure 6. The dynamic coefficient, in this case, has the value:

$$c_d = \frac{\Delta_{din}}{\Delta_{static,total}} = \frac{2{,}047e^{-2}}{2{,}35e^{-2}} = 0{,}871 \qquad (3).$$

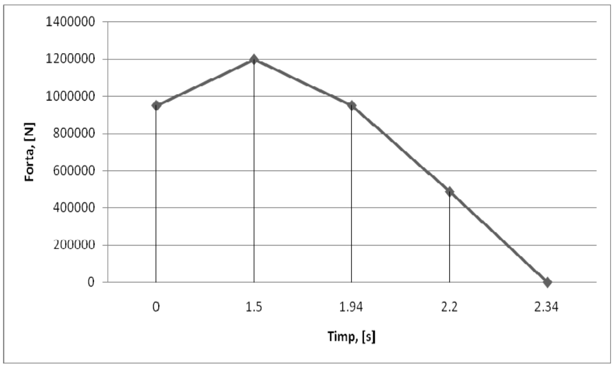

Figure 5. The variation of the hook load during the drill pipe's stuck in elevator

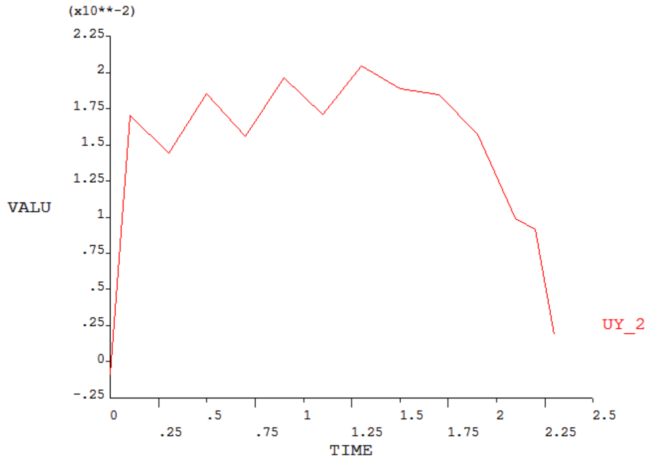

Figure 6. The dynamic response for the node 557

c). When the Top Drive works:
In figure 7, the torque`s variation during the drill string`s rotation, given by the Top Drive`s functioning, is presented. The dynamic response of the structure, in the modal method, for the node 589 (situated on the guideway girder TD at 35 m from the floor) is presented in figure 8 (Oy displacement) and in figure 9 (rotation made about Ox).

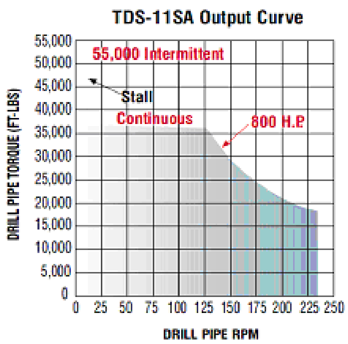

Figure 7. TDS 11 SA –Drill pipe torque versus rpm

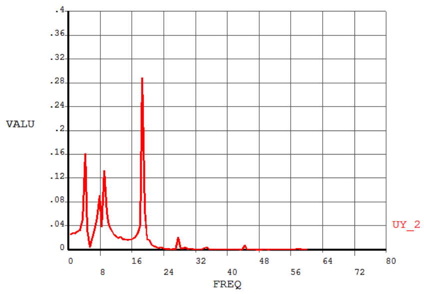

Figure 8. Node 589- Oy displacement

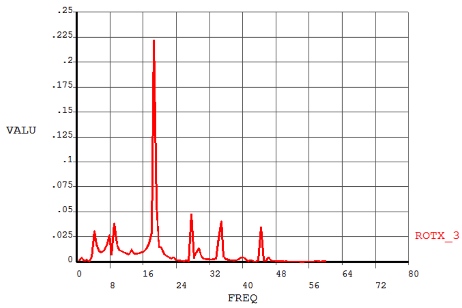

Figure 9. Node 589-rotation about Ox

The dynamic coefficient, in this case, is:

$$c_d = \frac{\Delta_{din,total}}{\Delta_{static,total}} = \frac{0,288}{0,248} = 1,1613 \qquad (4)$$

5. CONCLUSIONS

The static response was obtained for the hypothesis for which the following loadings are taken into account:

- total weight of the structure, including lifting equipment;
- loadings from the draw works drum socket and from the blind end, given by drill string weight;
- loadings from the maximum static hook load;
- loadings from the draw works drum socket and from the blind end, given by the maximum static kook load;
- loadings given by drill pipes stands` weights;
- loadings (on the mast and on the drill pipes stands) given by wind velocity of 30 km/h.

During this static analysis, the dynamic mast TD 320-43R was considered to be in the working position.
The dynamic response was obtained for the following loading cases:

- drill pipe pulled out from elevator;
- drill pipe stuck in elevator;
- stress caused by engine torque, applied at 35 m from the floor.

By determining the dynamic response of the metallic structure (both in the time domain and in the frequency domain), permanently analyzed in comparison to the static one, they could be highlighted the ratio between the dynamic response's values (displacement, rotation) and the static ones and, on the other hand, the phenomena of re-arranging of the most stressed elements. They observed that the most static stressed elements are not the most dynamic stressed ones.
The greater ratio between the dynamic response and the static one is given by the load variation during the drill pipes pulling out from elevator and during the Top Drive's working at a height about 35 m from the floor- the value of 1,195, as it was obtained with formula (2). Thus, given the very small ratios the dynamic and static responses (below the limit of 1,30, which is acceptable in engineering practice in order to capture the effect of the dynamic loads` applying), it can be said that, for this dynamic mast 320-43R, decisive for the dimensioning calculus is the static calculus. Of all the presented graphs, it resulted that the dynamic mast's nodes` displacements have normal values, allowing a properly working of this dynamic mast.
Since the metallic structures (masts, derricks) are submitted during their working to many dynamic loads, a dynamic recording is necessary, at the loading test made in factory. This recording is specific for the operations made during working and it must be introduced in the technical documents of the structure, with the specification that all the mentioned conditions must be respected during handling/working.
Given the dynamic characteristics of the metallic structure, the degradations` detection for such a structure must begin with a dynamic test of the kind made at the first test, which could highlight the new dynamic characteristics of the studied structure.
The comparison of the dynamic response of the damaged metallic structure with the initial dynamic response (realized in factory) allows the highlighting of the resistance capacity of the damaged structure and, consequently, the severity, the type and the location of degradations. All that information is useful in order to evaluate the real state of the structure.

BIBLIOGRAPHY

[1]. Dan G., Lungu L.D. - *Siguranţa construcţiilor, Institutul de construcţii Bucureşti*, 1973.
[2]. Popovici, Al., Niculae, G. C., Ene, C. D.- *Calculul şi construcţia utilajului pentru forajul sondelor de petrol*, Editura UPG Ploieşti, 2005.
[3]. Posea N. - *Calculul dinamic al structurilor*, Bucureşti, Editura Tehnică, 1991.
[4]. Posea N., Popa I.- *Metoda elementului finit în mecanica structurilor*, Editura Universităţii Petrol – Gaze, Ploieşti, 2006.
[5]. Said C.- *Cercetări privind dinamica sistemului de forare şi vibraţiile masturilor*, Teza de doctorat, Ploieşti, 1990.
[6]. Said C. - *Analiza dinamică a masturilor de foraj la operaţii de manevră*, Studii şi cercetări de mecanică aplicată, Tomul 50/ 3 - 4 – Mai - August 1991, Editura Academiei Române, 1991.