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RESEARCH

Research Regarding Drilling Masts Reliability under the Combined Action of the Wind and the Hook Load

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A B S T R A C T

Portable masts are parts of mobile servicing rigs designed to work at drilling or extraction wells and are made of three sections: fixed section, lower section and upper section. During transportation, the mast is placed in a horizontal position on a truck chassis, with the upper section nested inside the lower section. Before putting into service the mobile servicing rig, the lower and upper sections are erected as a unit, in a slightly inclined position. In this paper, the authors present the results of a research regarding the safety in functioning for such a mast which is under the action of the wind with high velocities. The wind's action direction with respect to the mast is analyzed in two cases: front-back and lateral, with stress and strain values that occur.

1. GENERAL CONSIDERATIONS

Masts are equipment of high importance entering the composition of the drilling rigs or well service rigs and are designed to be used on very long term.

Transportable masts subject to the work herewith reach in operation a 5-7 ° inclination against vertical position. This is the reason why they are equipped with one or two rows of resistance anchors. Also they are equipped with safety anchors to be fixed at the upper side of the mast. In stress or stability calculations, the only considered will be resistance anchors.

Safety in operation for drilling masts assumes fulfilment of three sensible requirements: under action by external loads, no element of the mast should give in (break down); mast in its assembly as well as elements of its composition should not lose their stability (should not give in by buckling); under action by either longitudinal or transversal wind, mast shall not be endangered to be overturned ([1], Chapter 7).

In the work herewith, aspects will be considered related to safety in operation of a portable mast under the action of the wind from lateral or transversal side direction. The mast is part of a T50 workover rig (Fig. 1), having a maximum load at hoisting hook, with chassis anchors, of 500 kN and a checkout static load, with chassis anchors, of 700 kN. Its height is 21 m (measured from ground to the inferior part of the crownblock) and reaches in operation a 5.3 °

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inclination against vertical position. This mast is an indeterminate structure, having a U-shape cross-section (Fig. 2b) and is made out of three parts: fixed, lower and upper sections (Fig. 2a). The component elements are beams made out of standard profiles, such as: Ø168.3x16 (EN 10305), L120x120x12, L100x100x10, L60x60x6, L80x80x6 (SR EN 10056-1), 100x60x6 rectangle, HE 200M (EN 1993-1), and their steel is S355J2- (SR EN 10025-2).

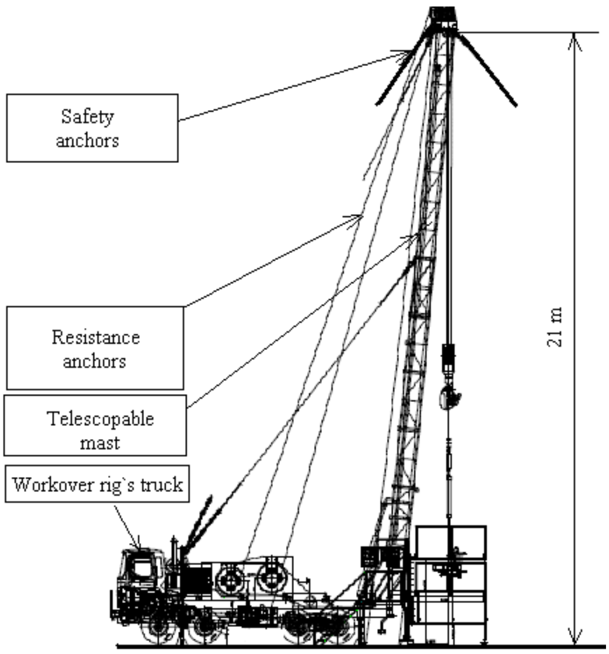


Fig.1. Workover rig ([10])

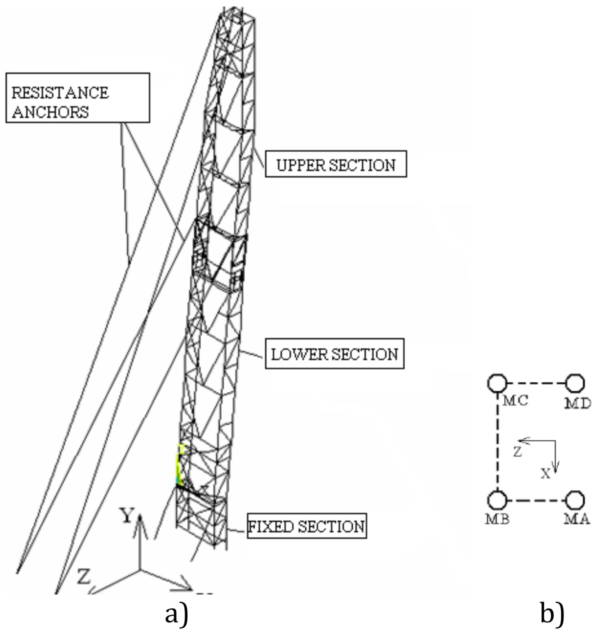


Fig. 2. Calculation model of a portable mast. a) assembly view; b) cross section throughout the mast.

2. ACTION OF LONGITUDINAL WIND TO UNLOADED MAST

Standard of the concerned range [1] provide that masts should be calculated also to wind rates of 120 km/h. In this analyzed case, mast is driven by dead weight, by weight of the hoisting system and by wind having 120 km/h velocity, acting in reverse direction versus the general axis Z (Fig.2, a). With formulae and indications specified in standard, loads given by wind were calculated for all elements exposed to wind (in accordance with [2-4]), that are to be further allocated to the nodes of the structure. Calculation of mast was achieved by the finite element method, using ANSYS program [5-9]. It can be noticed that bending moments and axial forces are predominant, which means that this kind of constructions as masts are submitted, from a theoretical point of view, to a combined axial and flexural stress [6,8,11].

The calculation group has an aim at determining stability on mast overturning under dead weight and under hoisting system weight.

The deformed shape of the mast under action by 120 km/h velocity of wind is shown in Fig. 3.

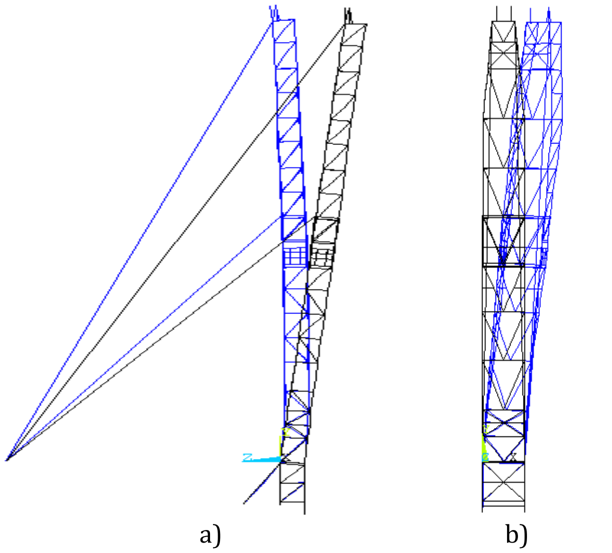


Fig. 3. Unloaded mast's deformed shape under the action of 120 km/h wind velocity, a) longitudinal wind case; b) transversal wind case.

It can be noticed that mast goes towards the back that means it has an overturning trend. In this case it is necessary that unloaded mast should be anchored to ground by means of safety anchors, in order to prevent an eventual fatal damage of the rig and its component parts [12]. However, in such situation, axial forces of elements located on MA and MD pillars (Fig. 3b), connecting fixed section to the lower one, are positive (strain forces) which means that mast has a trend of overturning in the back.

3. DRESSING THE RELIABILITY CHART FOR MAST SUBJECTED TO WIND ACTION

3.1. Longitudinal wind on mast

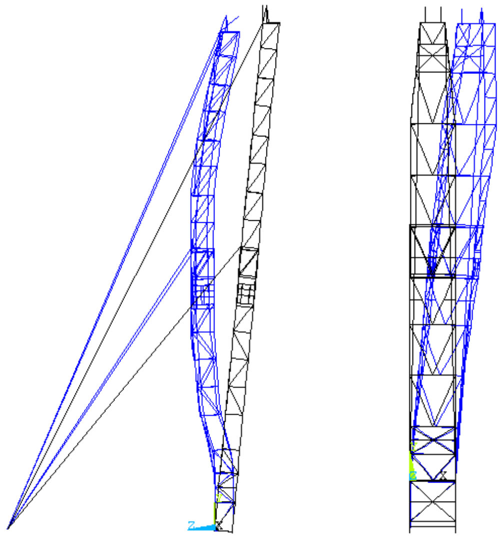
Due to longitudinal wind action from front to back of the mast (on direction of Z axis Fig. 2a), mast may have the trend of overturning in the back.

However, the hook load opposes this trend of the mast overturning in the back. For a certain wind velocity, the bigger the hook load is, the more such overturning trend of the mast decreases.

In order to study this mast overturning trend under action by the wind, plenty of calculations were needed. For a certain velocity v_1, forces were calculated on elements exposed to wind and they were introduced on mast at their ends. For a certain hook load, calculation of the structure was achieved and axial forces determined in elements on pillars MA and MD (located in the mast front side, Fig. 2,) connecting fixed section to lower section.

A same wind velocity was kept while modifying the hook load and axial forces were recalculated in these elements. The procedure was repeated by decreasing each time the hook load until the time that, for a certain value of such Q_{c1}, strain axial forces have occurred in the concerned elements. At that moment, mast was considered to have the trend of overturning and, thus, a point $P_1(v_1, Q_{c1})$ was obtained. The deformed shape of the mast at this moment, deemed to be critical, is shown as an example in Fig. 4.

For another value v_2 of wind velocity, a new value was obtained in the hook load for which axial forces in elements on pillars MA and MD (Fig. 2b) connecting fixed section to lower section become strain forces.



a) b)

Fig. 4. Loaded mast`s deformed shape under the action of wind, a) for longitudinal wind; b) for transversal wind.

These points were represented on a system of axes $v - Q_c$ by the union of which the curve in figure 5 was obtained. This curve divides plan $v - Q_c$ into two zones: one for which mast operation is estimated to be safe and the other for which it is estimated there is mast overturning trend.

The review of the diagram presented in Fig. 5 results in an estimate that, for longitudinal wind velocities less 70 km/h, under action by dead weight and weight of hoisting system, mast will not show any trend of overturning.

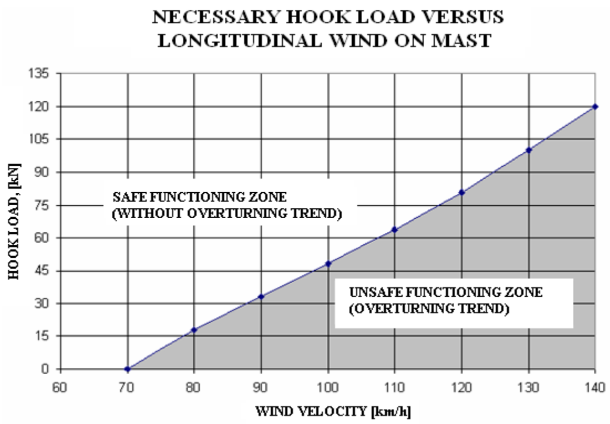


Fig. 5. Reliability diagram of mast under longitudinal action of wind.

3.2. Transversal wind on mast

A similar procedure as in the case shown above under paragraph 4.1 was run, but this time for wind action on mast from lateral side (on direction of axis X, Fig. 2a and 2b). After multiple calculations the chart of hook load variation versus wind velocity was obtained for which there is no trend of mast lateral overturning. In this case, a criterion in the calculations was to obtain positive axial forces in at least one of the elements located on pillars MC and MD (Fig. 2b) connecting fixed section to lower section.

As an example, in Fig. 4b the mast's deformed shape is shown under the action of lateral wind for a certain wind velocity and for a certain hook load. The chart obtained in this case in the system of axes $v - Q_c$ is shown in Fig. 6.

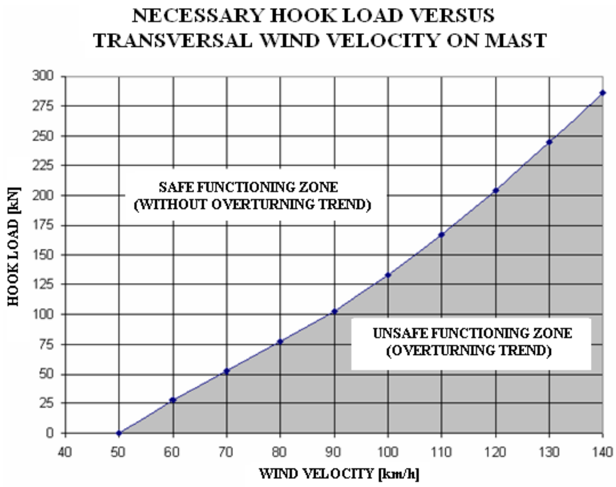


Fig. 6. Reliability diagram of mast under the action of transversal wind.

Construing of data shown in this diagram shall be done likewise for the case previously shown. An increase is noticed in the hook load for a same speed of the wind compared to the beforehand situation, for which there is no hazard of mast overturning. This can be explained by the wind direction being perpendicular onto the plan composed of mast axis and hook load direction.

4. CONCLUSIONS

a) The reliability of the drilling masts requires, among other things, that under the action of longitudinal or transversal wind they present no danger of overturning.

b) Transportable masts are equipped with one or two rows of resistance anchors and with safety anchors strength fixed to the top of the mast. The strength of materials calculations ([1]) and stability calculations take into account but only the resistance anchors.

c) Under the action of the longitudinal wind on the mast (along Z axis, Fig. 2a) with a velocity of 120 km/h, mast moves back and tends to overturn. In this case it is absolutely necessary that mast without hook load to be anchored to the ground with safety anchors.

d) Also, under the action of transversal wind (along X axis - Fig. 2a) with a velocity of 120 km/h, the unloaded mast with hook load presents a trend of overturning, which requires mandatory use of safety anchors.

e) The presence of hook load on masts provides an added stability to the action of wind, both longitudinal and transversal to the mast.

f) The reliability diagrams drawn in Figs. 4 and 5 shall emphasize safe functioning zones for the two analyzed cases of wind action on the mast, combined with the hook load.

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