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# The Study of The Static Behaviour of A Transportable Mast in Case of The Overload Test

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## Abstract

*In this paper, it is analyzed the static behaviour of a transportable mast, in the case of the overload test. The analyzed mast is made out of three parts: the fix part, the inferior part and the superior part, composing a complex spatial structure, statically undetermined. In its aggregate, the mast is made out of spatial straight beams, four anchoring cables (two, fixed at the crown block's level and two at the top of the inferior part) and two struts, considered as elements with articulated nodes. The overload test is an exceptional loading and, to analyze the mast's behaviour in this case, the authors used the finite elements method (FEM). The evaluation of all forces, based on STAS 1909/89 and ATI- 4F, leaded to the determination of some displacements and stresses for all the finite elements, using a specialized program. The stress analysis for all pillars` elements makes obvious the fact that the most strained elements are those from the close vicinity of the block and those from the parts` interpenetration zone, where big values of the bending moments occur. Also, the authors concluded that the biggest displacements are found at the crown block`s level.*

**Keywords**: *transportable mast, static behaviour, overload test, stress, displacement.*

## The constructive analysis of the mast

The masts are complex metallic constructions which are part of the drilling rigs. With their aid, they can rich a large variety of operations during the drilling process, the most important being the run in/pulling out hole.

The mast MU 180-37 is a transportable mast, made out of three parts: the fix part, the inferior part and the superior part (see figure 1). During the transportation, the mast is set in a horizontal position on the truck chassis, with the superior part introduced into the inferior part. Before the putting into service, these two parts must be brought to a quasi-vertical position, gently inclined at a $3^0$ 35' 24'' angle and, after this operation, the superior part is extracted from the inferior one by a telescoping manoeuvre, so insuring a total height of 37,1 m from the ground level. At the top of the superior (mobile) part, which has been telescoped, the crown block is set.

In the functioning position, the mast is anchored to the ground with safety anchors and to the truck chassis with four resistance anchors (two, fixed at the crown block level and the other two at the top of the inferior part).

The mast, in its aggregate, is a spatial construction which, in cross-section, has the letter “U” form (see figure 2) and is made, mostly, of hollow section beams and, also, of U sections, I sections and cassette sections.

The inferior part is made out of: four pillars (MA, MB, MC, MD in figure 2), built of OL 52.4 steel with a Φ 146x12 pipe cross-section; horizontal beams built of OL 37.4 steel, with a U 16 section; diagonal beams built of OL 45 steel, with Φ 76x5, Φ 89x5 and Φ 89x10 section (hollow sections).

The superior part has the pillars made out of Φ 146x10 pipes, the horizontal beams of U 16 section and the diagonal beams of Φ 76x5 hollow sections.
On the lateral faces of the mast MA-MB and MC-MD, on the both parts, there are common diagonal beams excepting the portions from the close vicinity of the interpenetration zones, where, on the two parts, the diagonal beams have the “X” letter form. On the back face of the mast, MB-MC, on the two parts, the diagonal beams are set in the “V” letter form.
The masts` beams are rigidly fixed by welding procedures at their nodes.

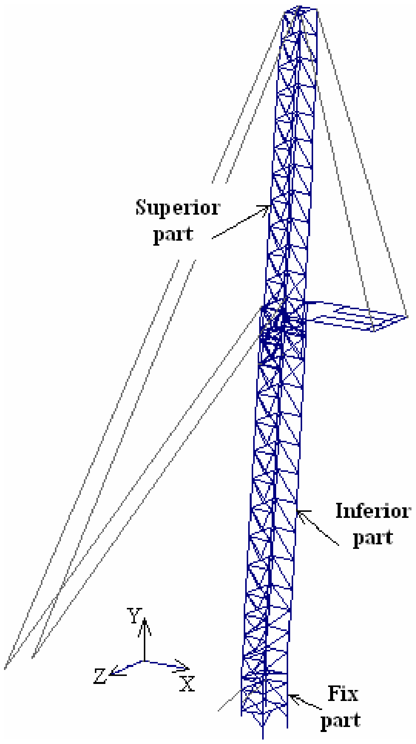


**Fig. 1.**

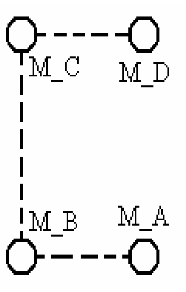


**Fig. 2.**

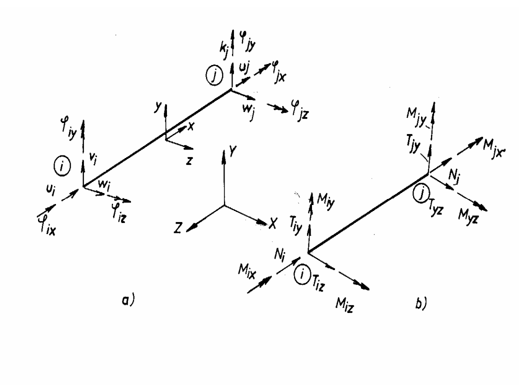


**Fig. 3.**

## The calculus model

From the static point of view, the mast represents a spatial structure made of many beams rigidly fixed at their nodes, statically undetermined. For such a structure, the most advantageous method to determine the stresses and displacements is the displacements method, which is the finite elements method's basis. In this case, each beam is a finite element.
Starting from these considerations, the authors elaborated a calculus model for the finite elements analysis. They used two types of finite elements: BEAM 3D (space beam type element having elastic nodes) and TRUSS 3D (spatial network element type). In the BEAM 3D element type case, these ones have six degrees of freedom, three displacements u, v, w and three rotation angles $\varphi_x$, $\varphi_y$, $\varphi_z$, which are considered to be positive when they have their vectors in the same direction with the coordinate axis both at the *i* edge and *j* edge of the element (see figure 3, *a*).
The cross-sectional efforts from a common beam edges *i-j* ($N_i$, $T_{iy}$, $T_{iz}$, $M_{ix}$, $M_{iy}$, $M_{iz}$, $N_j$, $T_{jy}$, $T_{jz}$, $M_{jx}$, $M_{jy}$, $M_{jz}$) are considered to be positive when they have their vectors in the same direction with the coordinate axis (fig. 3, b).

## Loadings evaluation

According to STAS 1909-89 and API-4F, the loadings that strain the mast can be divided in three categories: permanent loadings, temporary loadings and exceptional loadings.
Permanent loadings are due to the following causes:
- the mast weight force;
- the forces due to anchoring cables pre-clamping (of 12 kN);
- loadings at the draw works drum socket and the blind end due to hoisting equipment's weight (hook-block, cable and top drive), of 100 kN.

Temporary loadings can be:
a). main temporary loadings:
- drill pipe string's weight, considered to be, for the calculus, of 1350 kN;
- draw works drum socket and blind end loadings, due to drill pipe string's weight, considered to be 221,923 kN and 149,923 kN, respectively;
- loadings due to drill pipes stands stack (4 ½ in drill pipes for a 5200 *m* length or 3 ½ in for 7000 m).

b). secondary temporary loadings
- loading from the maximum static force (of 1800 kN), that appear during the well casing and workover operations only;
- loadings due to wind action.

Exceptional loadings consists in a force due to the overload test, $Q_p$= 1,25$Q_{\max}$= 2250 kN. It is applied to the mast, together with all forces that arise from this loading (corresponding forces, from draw works drum socket and blind end) and permanent loadings. The overload test forces are introduced in the calculus model nodes, at the crown block level.
According to the mentioned standards, the groups of loadings are the following:
- main fundamental groups, including the corresponding loadings due to the functioning with drill pipes without the wind action;
- secondary fundamental groups, including the corresponding loadings due to: the functioning with drill pipes and under wind action; the functioning with drill pipes and without wind action; the functioning without drill pipes, without wind action; the repose with drill pipes and under wind action.
- special groups, where STAS 1909/89 includes the overload test and API-4F includes, moreover, the hurricane action.

## Stresses in pillars and crown block's displacements due to overload test

The overload test is a special group of loadings in which case $\sigma_a$= 300 MPa (STAS 1909-89). The maximum intensity of σ is determined using the following formula:

$$|\sigma|_{max} = \frac{|N|}{A} + \left|\frac{M^y}{W_y}\right| + \left|\frac{M^z}{W_z}\right| \quad (1),$$

for cross-sections that can be included in a full-corners rectangle and with formula (2) for annular cross-sections:

$$|\sigma|_{max} = \frac{|N|}{A} + \frac{|M^i|}{W} = |\sigma^N| + |\sigma^M| \quad (2),$$

where $|M^i|$ is presented in formula (3) for the annular cross-sections.

$$M^i = \sqrt{(M^y)^2 + (M^z)^2} \quad (3),$$

The stresses in the most strained pillars` elements, determined using formula (2), are indicated in table 1. A few elements` positions are given in figure 4.

From table 1 we can see that the maximum stresses appear in element 270, found on pillar MA ($\sigma_{max}$= 300 MPa, in absolute value) and in element 315, on pillar MD ($\sigma_{max}$= 298 MPa, in absolute value). Both elements are located on the superior part panel, in the interpenetration zone with the inferior part. Their values are close to the material's allowable stress for this group of loadings.

Big values are recorded also in elements 296 and 311, situated at the top of the superior part (as we can see in figure 5). For the rest of the panels elements, the maximum stresses values are inferior to the allowable stress $\sigma_a$= 300 MPa. So, we can conclude that the mast's behaviour is an elastic one.

**Table 1 – Stresses in the most strained elements**

| Elem. No. | $\sigma^N$ MPa | $\pm\sigma^M$ MPa | $\|\sigma\|_{max}$ MPa | Elem. No. | $\sigma^N$ MPa | $\pm\sigma^M$ MPa | $\|\sigma\|_{max}$ MPa |
|---|---|---|---|---|---|---|---|
| 7 | -141 | 99 | 240 | 270 | -221 | 79 | 300 |
| 10 | -140 | 98 | 238 | 280 | -158 | 63 | 221 |
| 51 | -155 | 82 | 237 | 285 | -119 | 156 | 275 |
| 52 | -88 | 142 | 230 | 296 | -196 | 94 | 290 |
| 69 | -98 | 117 | 215 | 300 | -123 | 143 | 266 |
| 86 | -95 | 117 | 212 | 309 | -175 | 46 | 221 |
| 102 | -150 | 83 | 233 | 311 | -186 | 92 | 278 |
| 103 | -87 | 138 | 225 | 313 | -98 | 122 | 220 |
| 268 | -108 | 132 | 240 | 314 | -121 | 88 | 209 |
| 269 | -132 | 92 | 224 | 315 | -207 | 91 | 298 |

We present the displacements *u, v, w* of the pillars` nodes situated at the crown block level (fig. 6), for this loading case. The displacements along *OX, OY, OZ* axis of the general coordinate system (*u*- displacement along *OX*; *v*- displacement along *OY*; *w*- displacement along *OZ*) are indicated in table 2. The crown block's deformed form due to the overload test is shown in figure 6, where, also, the general axis *OX* and *OZ* are presented (obviously, the *OY* axis is vertical).

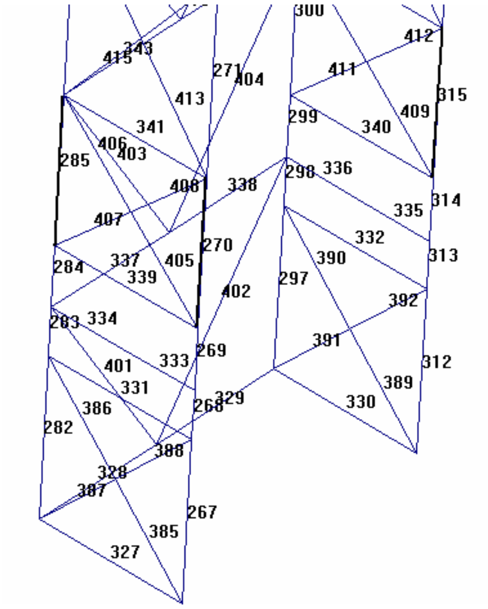


**Fig.4**

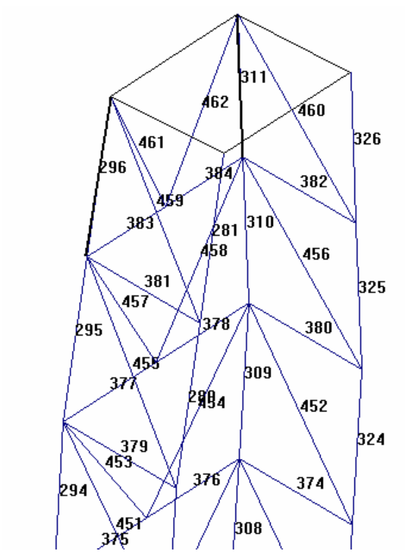


**Fig. 5**

**Table 2. Displacements of crown block's nodes [mm]**

| 122 | | | 123 | | | 124 | | | 125 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *u* | *v* | *w* | *u* | *v* | *w* | *u* | *v* | *w* | *u* | *v* | *w* |
| 144 | -34 | 0.1 | 124 | -33 | 0.1 | 124 | -40 | -16 | 144 | -43 | -16 |

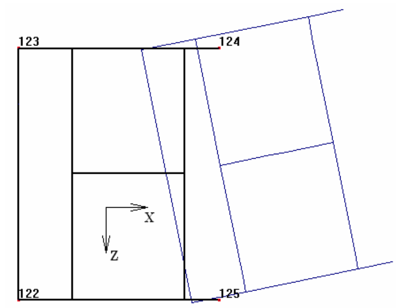


**Fig. 6.** Crown block's non-deformed and deformed form

## Conclusions regarding the mast's resistance

The mast is a complex spatial structure, made out of spatial straight beams, four anchoring cables (two, fixed at the crown block's level and two at the top of the inferior part) and two struts, considered as elements with articulated nodes.

The evaluation of the loadings, based on STAS 1909-89 and ATI-4F, leaded to the determination of some displacements and stresses for all the finite elements and the calculus was made by using a specialized program.

The stresses determined in the case of the overload test are very big. The maximum values occur in element 270 of the pillar MA ($\sigma_{max}$= 300 MPa) and in element 315 of the pillar MD ($\sigma_{max}$= 298 MPa). Both elements are situated on the panel of the superior part, in the interpenetration zone with the inferior part. Their values are at the limit of the material's allowable stress for this kind of loading ($\sigma_a$= 300 MPa).

The stress analysis for all pillars` elements makes obvious the fact that the most strained elements are those from the close vicinity of the block and those from the parts` interpenetration zone, where big values of the bending moments occur because the moment from the superior

part's section (above the link zone) is transmitted to the inferior part as a force couple with small arm. The authors suggest that this situation can be improved if a solution for an efficient collaboration, in the bending case, between the pillars` elements of the both parts, in their contact zone, is found.
The nodes` displacements are given in table 2 for the crown block's nodes and, obviously, they are the biggest. The biggest displacement at the crown block's level has the maximum value, of 144 mm, along the general axis *OX*.

## References

1. Posea, N. – *Rezistenţa materialelor*. Editura Didactică şi Pedagogică. Bucureşti, 1979.
2. Posea, N., Popa, I. – *Metoda elementului finit în mecanica structurilor*. Editura Universităţii Petrol-Gaze din Ploieşti. Ploieşti, 2006.
3. STAS 1909/89. *Turle si masturi pentru foraj si interventie. Prescriptii de calcul si proiectare.*

# Studiu privind comportarea statică a unui mast transportabil la proba de suprasarcină

## Rezumat

*În această lucrare, este analizată comportarea statică a unui mast transportabil la proba de suprasarcină. Mastul analizat un mast transportabil alcătuit din trei tronsoane: tronsonul fix, tronsonul inferior şi tronsonul superior, alcatuind o structură spaţială complexă, multiplu static nedeterminată. În ansamblul său, este format din bare drepte spaţiale, patru cabluri de ancoraj (două la nivelul geamblacului şi două la partea superioară a tronsonului inferior) şi două contrafişe considerate ca elemente articulate la noduri. Proba de suprasarcină este o incarcare exceptionala, iar pentru analiza comportării mastului în acest caz s-a folosit metoda elementelor finite. Evaluarea tuturor forţelor, realizată pe baza STAS 1909/89 şi ATI-4F, a condus la determinarea unor deplasări şi tensiuni pentru toate elementele finite, folosindu-se un program specializat. Analiza tensiunilor rezultate pe toate elementele montanţilor pune în evidenţă faptul că, cele mai solicitate sunt cele din imediata vecinătate a geamblacului şi a celor din zona prinderii dintre tronsoane, unde se dezvoltă în elemente momente încovoietoare relativ mari. De asemenea, s-a constatat că, cele mai mari deplasări se gasesc la nivelul coroanei geamblacului*.