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Calculation of Resistance of the Drilling Installation F100's Mast

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Abstract

The paper presents the calculation of stresses and displacements in all the elements of the drilling installation F100's mast. The installation can be transported by a lorry, is equipped with a MU100, U-shaped, telescopic mast. The resistance structure is composed of: the lorry's chassis, the fixed section including stabilizers, the lower section, the upper section, the crown block, the monkey board, the stabbing board, the resistance anchor and the ground anchor. The calculation was done with the finite element method. The results allow the optimization of structure and decreasing the usage of material, in full compliance with the conditions of resistance.

Key words: *mast, transportable installation, monkey board ,stabbing board.*

Establishing the Geometric Model

The mast's geometric model is achieved by its discretization into finite elements of the BEAM type. The finite element nodes are determined by elastic nodes, i.e. nodes with six degrees of freedom. Nodes coordinates were determined in respect to the general system of axis XOYZ depicted in Figure 2. The system origin O was chosen in the middle of the crosspiece over the chassis hydraulic jacks, between nodes 57 and 58. The OX axis is the horizontal axis of symmetry for the chassis, with the positive direction towards the chassis backside, the OY axis is the vertical axis, with the positive direction upwards, while the OZ axis completes the rectangular cartezian coordinates. The vertical XOY plan is the mast`s symetry plan. The mechanical characteristics of the materials and the geometrical characteristics of the beams' sections are given for each element. The fixed section with stabilizers and the lorry chassis are modeled with nodes 1 to 7 (fig.2).The connections between the fixed section with stabilizers and the lower section are done by the nodes 67, 68, 69 and 70 while the ones between the upper section and the lower section are done through elements 149-209; 138-159; 139-160; 120-151 and 121-152. The upper section is connected to the lorry chassis by two resistance anchors 63-205 and 64-206. When on, the drilling installation is connected to the ground through 8 jacks in nodes 1 to 8 (fig. 2). If the wind is over $70\,{}^{km}\!/_{h}$, the upper section is anchored to the ground in nodes 205, 206, 207 and 208 while the crown board is anchored to the ground in nodes 231 and 232 (fig.3).

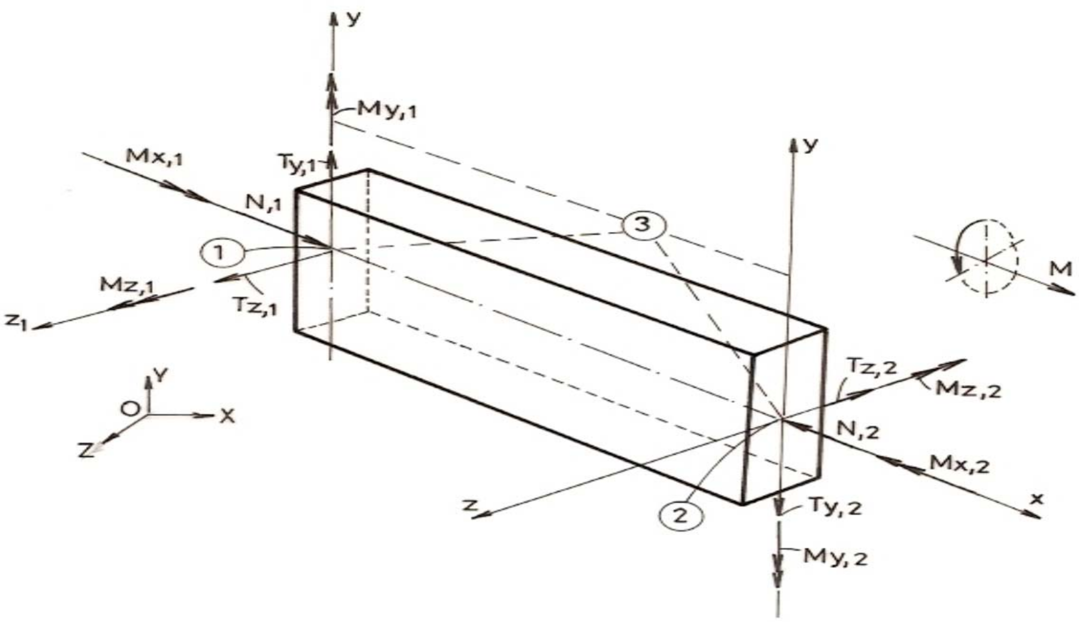

Fig. 1 The local coordinate system

Calculation of Forces in the MU100 Mast

Forces in the M100 mast were calculated and groupped according to the STAS 1909-89 [3] and the technical norms API Spec. 4F [5] regarding metallic constructions for drilling and intervention installations. External forces were groupped according to several scenarios outlined below:

∗ Scenario 1- Installation testing

- testing load in the crane's hook; $Q = 1250$ kN
- vertical and horizontal components of forces at the active and dead end of the maneuvering cable;
- own weigth of the mast elements;
- pre-tension forces on the anchors in the two situations – situation 1.1 with $F_a = 6$ kN and situation 1.2 with $F_a = 12$ kN ;

Table 1

Node	Loading Scenario														
	1.2			2.2			3.1.1			3.2.1			3.1.3		
	Displacements (mm)														
	u	*v*	*w*	*u*	*v*	*w*	*u*	*v*	*w*	*u*	*v*	*w*	*u*	*v*	*w*
205	117	-19	8,5	173	-20	7	36,5	-3,3	0	37	-3,5	0	50	-4	18,5
206	126	-19	8,5	180	-20	7	36,5	-3,3	0	37	-3,5	0	41	-3	18,5
207	117	-23	15	123	-25	12	36,5	-3,3	0	37	-3,5	0	50	-5	12
208	126	-24	15	180	-26	12	36,5	-3,3	0	37	-3,5	0	41	-3	12
250	119	-19	8,5	175	-20	7	36,5	-3,3	0	37	-3,5	0	48	-4	18,5
251	124	-19	8,5	180	-20	7	36,5	-3,3	0	37	-3,5	0	43	-3	18,5
258	117	-21	12	173	-27	10	36,5	-3,3	0	37	-3,5	0	50	-5	15
259	126	-21	12	180	-23	10	36,5	-3,3	0	37	-3,5	0	41	-3	15
262	121	-22	12	177	-23	10	36,5	-3,3	0	37	-3,5	0	45	-4	15
265	121	-23	15	177	-20	12	36,5	-3,3	0	37	-3,5	0	45	-4	12

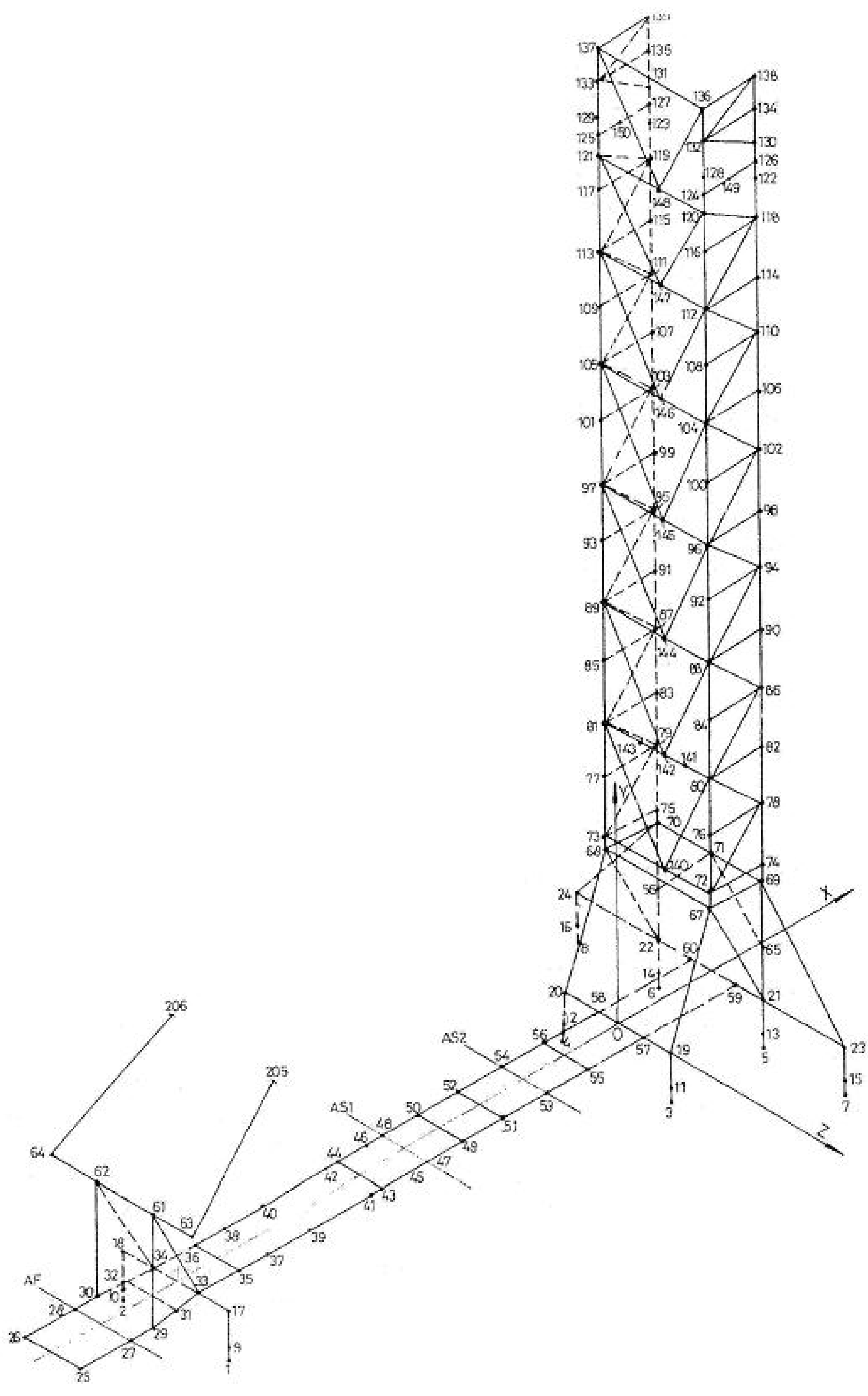

Fig. 2 Discretization into finite elements

*Scenario 2- Installation is working , $v = 70\ \mathrm{km/h}$ wind

- maximal load in the crane's hook $Q = 1000\,\mathrm{kN}$;
- vertical and horizontal components of forces at the active and dead end of the maneuvering cable;
- own weigth of the mast elements;
- push forces of the drilling rods over the crown board.

Table 2

Element	Node		σ_{ech} (N/mm^2)				
			Loading Scenario				
	i	*j*	1.2	2.2	3.1.1	3.2.1	3.1.3
5	5	13	153	100	96	80	130
6	6	14	156	110	97	80	0
7	7	15	104	94	56	54	180
8	8	16	100	89	56	47	0
58	55	57	97	101	91	86	79
60	57	59	82	87	69	66	100
74	19	67	105	66	55	44	50
75	20	68	94	57	55	41	36
78	65	69	121	134	60	51	69
79	66	70	124	136	60	45	46
99	74	78	160	172	66	57	81
100	75	79	163	172	66	49	40
103	78	82	150	155	47	40	57
104	79	83	158	164	48	35	28
107	82	86	150	158	50	42	60
108	83	87	159	168	51	37	29
217	149	126	127	124	10	8	11
218	150	127	118	117	10	16	11
252	209	153	230	203	15,5	16	36
257	210	156	242	238	28	25	41
258	153	157	158	146	37	30	25
259	154	158	152	150	45	34	24
291	186	190	146	127	16	12	16
308	203	207	148	123	16	10	21
310	153	155	147	137	17	12	31
311	154	156	146	131	17	11	16
404	151	245	140	112	16	13	22
405	192	246	123	99	16	11	14
450	260	262	180	143	16	1	6
451	262	261	180	143	1	2	7
453	207	265	158	125	3,1	5	15
469	262	263	93,5	75	0	0	0
470	263	264	96	77	0	0	0
471	264	265	96	77	0	0	0
478	149	209	109	104	0	8	8
479	150	210	109	104	0	10	10

- forces in nodes generated by the $v = 70\ \mathrm{km/h}$ wind blowing parallel to the OX axis (worst case scenario)
- pre-tension forces on the anchors in the two situations – situation 2.1 with $F_a = 6\,\mathrm{kN}$ and situation 2.2 with $F_a = 12\,\mathrm{kN}$;

*Scenario 3 – installation is stopped, the pile of rods is in the monkey board and $v = 135\ \mathrm{km/h}$ wind

- own weigth of the mast elements;
- push forces of the drilling rods over the crown block;
- forces in nodes generated by the $v = 70\ {}^{km}/_{h}$ wind blowing parallel to the OX axis (worst case scenario);
- pre-tension forces on the anchors $F_a = 12$ kN;

This scenario has five cases:
3.1.1 - two stacks of rods without ground anchors;
3.2.1 - two stacks of rods with ground anchors;
3.1.1 - one stack of rods without ground anchors;
3.2.2 - one stack of rods with ground anchors;
3.1.3 - one stack of rods, sidewind from OY direction with $v = 135\ {}^{km}/_{h}$ speed
Wind forces are calculated according to STAS 10101/20-90 [4] and the API Spec 4F[5].

Displacements. Efforts. Stresses

For each scenario, after running the program we obtain the displacement of all nodes in respect to the coordinate system XOYZ. A node has six degrees of freedom: displacements *u*, *v*, *w* on the OX, OY, OZ axises and rotations φ_x, φ_y, φ_z around the same axises.

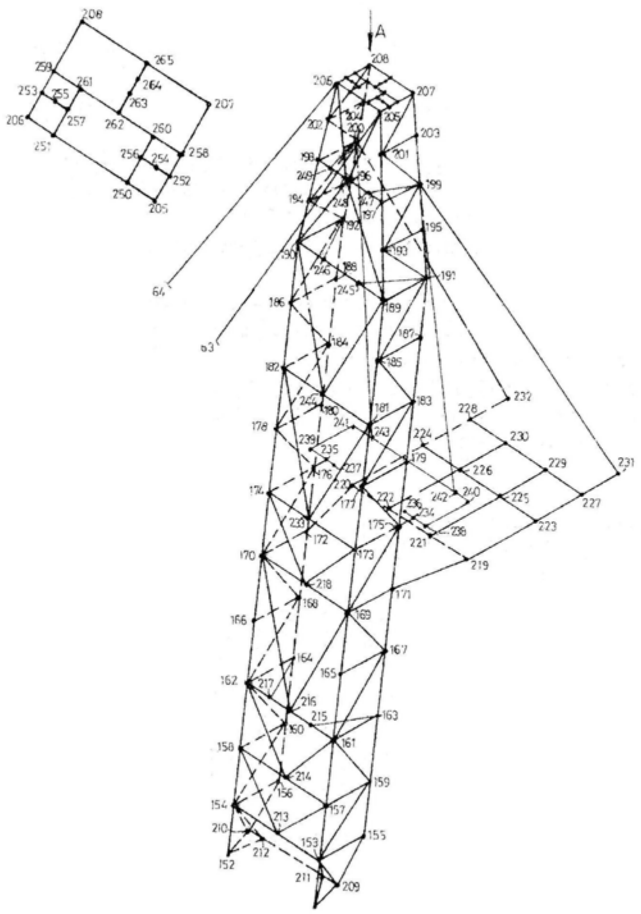

Fig. 3 The upper section and the crown board nodes

Sectional efforts are calculated in respect to the local coordinate system *xOyz* (Fig.1); *Ox* is the beam axis, from node 1 to node 2; *Oy*, situated in the 1-2-3 plane, normal to the local *Ox* axis and oriented towards node 3, being one of the main inertial axises for the beam section; *Oz* is the second main inertial axis and completes the right triorthogonal. The normal and tangent stresses are calculated with material resistance formulas according to composed stresses for spatial beams. The equivalent stress in the high stress element point is calculated according to the resistance theory of the potential deviation energy (von Mises).

Displacement of the nodes at the base of the mast and at the upper part (crown block zone) are listed in table no. 1. Section efforts, stresses σ and stresses τ were calculated in all structure nodes for all 9 loading scenarios. Table no. 2 lists equivalent stresses for loading scenarios 1.2 and 2.2, when stresses are higher.

Conclusions

The exact calculation of displacements and stresses in all the nodes of the MU 100 mast's resistance structure was done using the Finite Element Method. High displacements are registered in the upper part of the mast (crown board zone), where we have 190 mm in scenario 2.2.
The mast's supports are uniformly stressed, in all load scenarios. The resistance conditions are matched since their material is OL52, with allowable stress $\sigma_a = 250 \ {}^{N}\!/_{mm^2}$ [3]. The crown block`s elements are also uniformly stressed, with the high stresses in scenarios 1.2 and 2.2 being under the maximum admittable values, since the material used is the steel alloy 34MoCrNi16 with yield stress $\sigma_c = 800 \ {}^{N}\!/_{mm^2}$ and $\sigma_a = 600 \ {}^{N}\!/_{mm^2}$ [3].

In the resistance elements of the lorry chassis, the equivalent stress is under $100 \ {}^{N}\!/_{mm^2}$.

The results can be used to optimize the resistance structure and therefore lower the usage of metal while remaining safe in usage.

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Calculul de rezistență al mastului instalației de foraj F100

Rezumat

În lucrare este prezentat calculul de rezistență al mastului transportabil al instalației de foraj F100. Sunt analizate toate cazurile de încărcare, stabilindu-se trei scenarii diferite de solicitări. Sunt comparate tensiunile maxime cu cele admisibile ale materialelor utilizate.