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# NUMERICAL ANALYSIS OF DRILLING RIG'S CARRYING STRUCTURE

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**Abstract:** *Drilling rigs are constructions which play indispensable role in oil extraction process. The paper shows numerical calculations of crucial parts of drilling rigs which are derricks. These structures carry almost entire loading which occur during extraction of oil deposits. Level of von Mises stresses and total mass were the main criteria taken into account. A stability analysis was also done and buckling safety factors were estimated.*

**Keywords: Drilling rig, derrick, buckling.**

## 1. Introduction

Petroleum is one of the most needed energetic raw materials. Because of that its extraction is well-developed despite of many difficulties during realization of this process. The main problem is that oil deposits are usually situated several kilometres below ground level. To overcome this disadvantageous conditions special constructions called drilling rigs are used which enables to create drilling hole. Basic parts of a drilling device are mud pump, draw-works, drill lines and derrick. The latter is the main one in terms of mechanical stability as it serves as a carrying structure. It is under the influence of loading which acts through draw-works unit. The derrick has a truss structure with height up to several tens of meters. In the view of its working conditions, it has to be characterized by high mechanical strength and stability but on the other hand its mass must be as low as possible. These demands can be fulfilled by utilization of special profiles.

There are several loads that act on drilling rig's derricks. The most significant is influence of set of pipes. Among the others there are force of wind, travelling and fixed blocks or hooks.

One of other key problems in terms of durability of derricks is its dynamics. For this reason one have to include calculations of vibrations not only in the process of designing but also to examine their level during operation of the drilling rig. Example of such an attitude were described in details by plenty of researchers (among others Hu et al., 2013; Han et al., 2011). Usually the obtained results serve to conduct numerical simulations. In this way it is possible to calculate for instance first, second and so on order modes. This knowledge is the key to proper design of the construction.

## 2. Method

The goal of this work was to simulate and analyze loading and stresses in derrick under the influence of pipe set and then to optimize its geometry. The criterion was to keep level of stresses below permissible value while lowering construction's mass.

The simulations were carried out for the following parameters:

- Total length of the pipe set: 3000 m;
- Length of one pipe: 13 m;

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- Total mass of the pipe set: 230 000 kg;

- Yield stress of steel S235 used for construction: 235 MPa;

- Assumed safety factor: 2;

- Assumed buckling safety factor: 1.5;

- Permissible value of stresses: 117,5 MPa.

To perform simulations Siemens NX 9.0 software was used. Beam finite elements were utilized in numerical analyses.

An initial concept was to use I-beam profiles for main, oblique and transverse poles (Fig. 1a). In following simulations the dimension of this profile were modified. All of these dimensions are shown in Tab. 1. Another cross-section used in simulations was a closed one (Fig. 1b). Its dimensions are shown in Tab. 2.

There was a gap in the structure for placing the pipe set inside the derrick.

a) b)

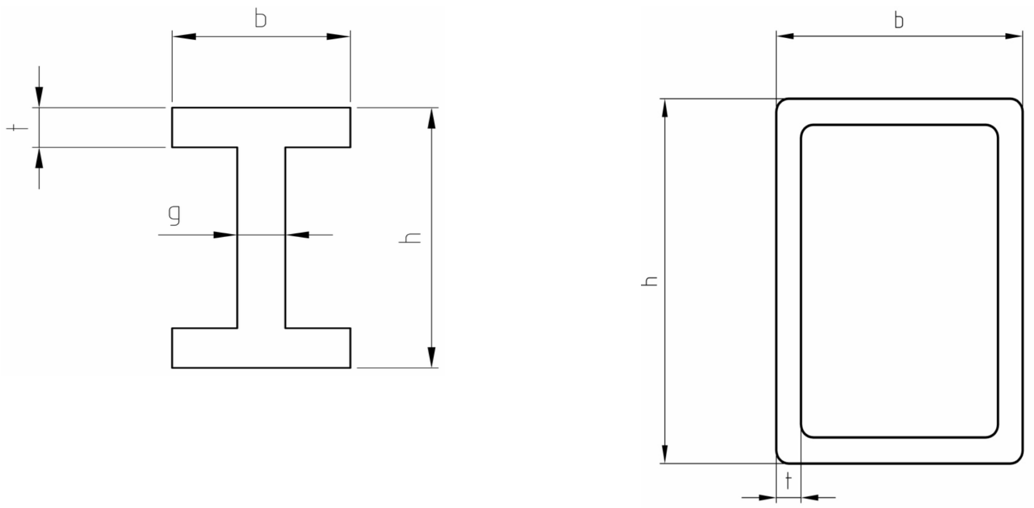


*Fig. 1: Two types of profiles used in analyses: a) I-beam, b) closed*

*Tab. 1. Dimensions of I-beam profile (according to Fig. 1)*

| | | h [mm] | b [mm] | g [mm] | t [mm] |
|---|---|---|---|---|---|
| **First concept** | **Main beams** | 497,0 | 200,0 | 8,4 | 14,5 |
| | **Additional beams** | 196,4 | 100 | 4,5 | 6,7 |
| **Second concept** | **Main beams** | 357,6 | 170,0 | 6,6 | 11,5 |

*Tab.2. Dimensions of closed profile (according to Fig. 1)*

| | Typ | t [mm] | b [mm] | h [mm] |
|---|---|---|---|---|
| **Main beams** | Square | 10 | 200 | 200 |
| **Additional beams** | Rectangular | 10 | 180 | 260 |

Successive simulations were carried out. Their results are presented in Fig. 2-4 and also in Tab. 3. One can point out that for all of the cases von Mises stresses were below permissible level what means that strength criterion was fulfilled. For the first concept they were almost twice smaller than it is acceptable what meant the construction was too massive. Having in mind the other criterion (mass reduction), it turned out that the second concept was better than the first one. On this basis the authors decided to choose between the second and the third concepts.

As stability of derricks is of a great importance, buckling was analyzed as well. Safety factor was calculated for all 3 concepts using numerical simulations again (Tab. 4). This parameter has values below 1,2 for second concept what is not enough to ensure derrick's stability. For the other cases this requirement was met. Comparing the dimensions of the structure for first and third concept, it turned out that the best profile for the derrick's structure with the given initial parameters is the third one. Its buckling safety factor has value higher than 11 what means there is no danger of instability occurrence during the operation of the drilling rig.

a) b)

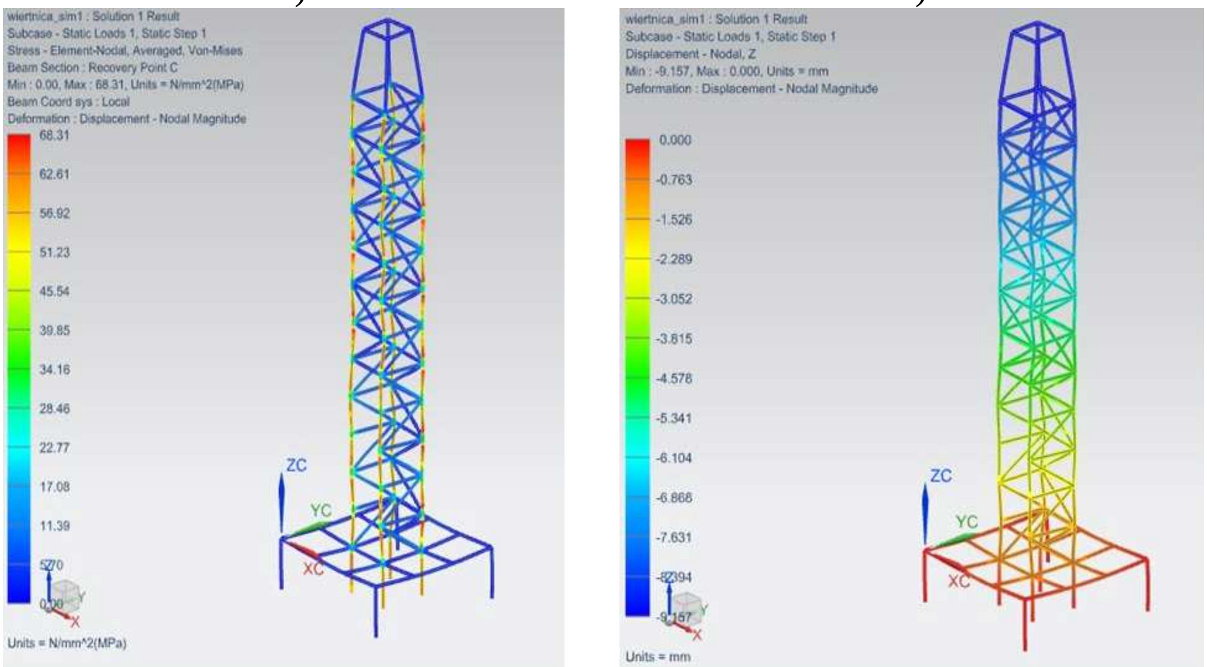


*Fig. 2. First concept: a) von Mises stresses [MPa], b) displacement [mm]*

a) b)

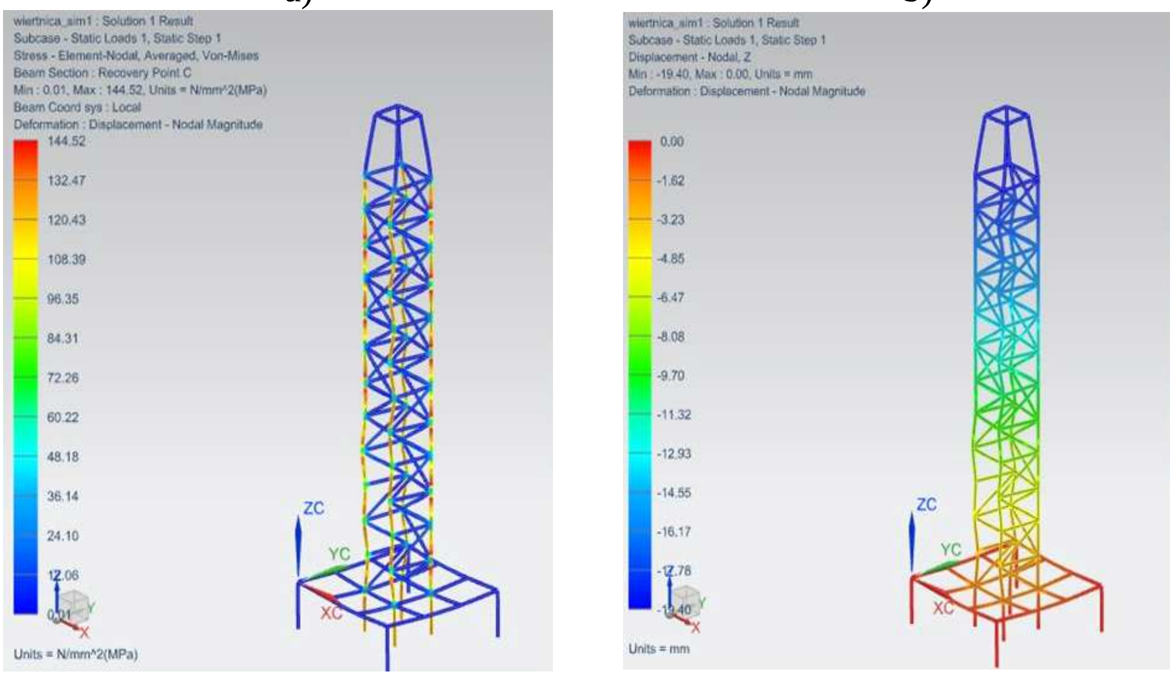


*Fig. 3. Second concept: a) von Mises stresses[MPa], b) displacement [mm]*

a) b)

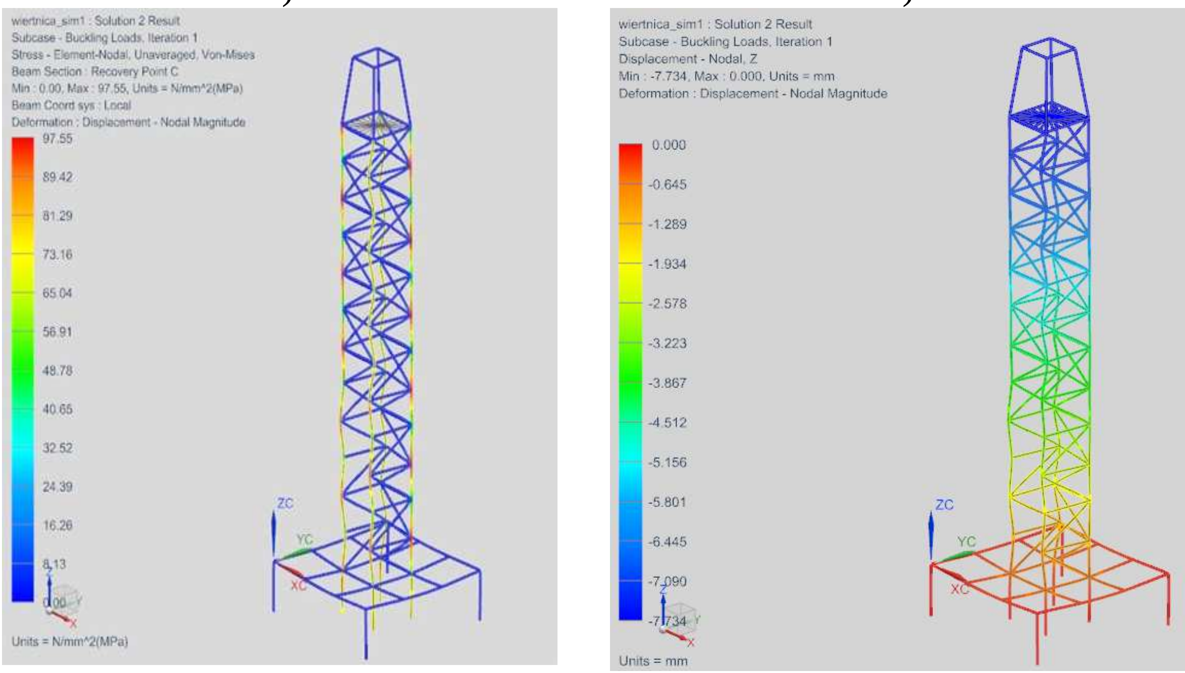


*Fig. 4. Third concept: a) von Mises stresses [MPa], b) displacement [mm]*

*Tab. 3. Results of simulations for 3 concepts*

| | First concept | Second concept | Third concept |
|---|---|---|---|
| **Maximum von Mises stresses [MPa]** | 68 | 109 | 98 |
| **Maximum displacement [mm]** | 9,2 | 14,6 | 11,5 |

*Tab. 4. Values of buckling safety factor for 3 concepts analyzed*

| **Concept** | **Buckling safety factor** |
|---|---|
| 1 | 1,57 ÷ 1,58 |
| 2 | 1,02 ÷ 1,18 |
| 3 | 11,5 ÷ 22,4 |

## 3. Conclusions

The carried out analyses helped to select the optimal profile for the derrick's structure in the view of the given criteria. The closed cross-section met all requirements: strength and buckling. Von Mises stresses were up to 100 MPa which is quite near to the permissible value of 117,5 MPa. I-beam profiles fulfilled the strength criterion as well but they were not enough safe in terms of buckling (the second concept) or they were too heavy (the first concept).

All in all, for the assumed values of input parameters, construction of derrick was designed. In addition dynamic analyses could be carried out but it was out of the scope of this paper.

## References

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