Parametric modelling and finite elements study for the boom of a truck crane

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Abstract. Parametric modelling and finite elements study for the crane boom was done in Catia V5R20 software. 3D modelling was done considering the load diagram. This is the basic feature for this study because it gives us information between the main elements (lifting capacity, outreach, boom length lifting height) which define crane operation possibilities. The truck crane is installed on the standard undercarriage of a truck or specially built undercarriages, the engine that drives the undercarriage serving either just for equipment travel or also for driving the crane mechanism. When the engine on undercarriage is only for travel, the truck crane is provided with an additional auxiliary engine, exclusively intended for crane mechanisms operation. The studied boom belongs to Liebherr crane. For parametric modelling measurements on an existing model were needed. Finite elements study was done on the basis of virtual model using a specialized soft. We did a static study by which we determined the static parameters of the structure (stresses, deformations, safety coefficient), for all own rates within interest range. The next aim, using the parameters, is to build the static model of reaction. Any static deformation of a structure can be represented as a weighted sum of structure’s own modes, each knot can be represented as a system with only one degree of freedom. This kind of study allows us to find which is the maximum deformation, the stresses and value of safety coefficient borne by a technical system or machinery under movement or static condition.

1. Introduction
The truck crane is a crane with boom, installed on the standard undercarriage of a truck, or on a specially built undercarriage, the motor driving the undercarriage serving either only for equipment travel or also for driving the crane mechanisms.

In case the motor on the undercarriage only serves for travel the truck crane is provided with an auxiliary, additional motor exclusively intended for operation of crane mechanisms.

Although there is a great variety of truck cranes, the constructive parameters are limited by the road traffic rules (such as overall size limits for travel on public roads, load on axles and other norms regulating vehicles travel on public roads, both nationally and internationally)[1].

Namely, increase of lifting capacity involves increase of the number of axles, which implicitly determines suitable increase of overall sizes, causing a certain difficulty of the transport from one destination to another.

Truck cranes on wheels with tyres are used in a greater and greater extent due to some undisputed advantages such as:
- great mobility respectively reduced time for changing work position from one object to another;
- most of the time additional personnel is not needed except for the crane operator;
- being equipped with driving systems independent from fixed power supply sources they are able to work under various situations like unarranged or with few arrangements fields;
- they have sufficient stability so that there is the possibility for crane to travel with hooked load;
- increased efficiency in operation is got, with suitable decrease of production cost.

The main feature of mobile cranes used within their activity is the load diagram. This is the basic feature of the cranes, as it is expressed between main elements that define operation possibilities of the crane namely:
- lifting capacity in kN;
- outreach in m;
- boom length in m and lifting height in m.

The components of a truck crane are:
- undercarriage with fixed platform and pressing-on earth devices,
- slewing platform with cab and superstructure equipment,
- the superstructure equipment (crane boom) driving system control installations and devices,
- safety devices,
- signaling devices and counterweight.

Characteristic for the truck cranes is that the travel is done through the truck engine.
The travel speeds prescribed are within 40-70 km/h.

Such type of cranes are lifting machines with crawler travel system, the fundamental difference between them and other types of cranes being their possibility to travel also when loaded.

2. Parametric modelling and finite elements study for the boom of a truck crane
Parametric modeling and finite elements stud for the boom of a truck crane were done for extreme lifting position under maximum load.

A leaflet from LIEBHERR was used as reference point [2].

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- lifting capacity in kN;
- outreach in m; boom length in m and lifting height in m.

Diagram reading is done knowing the value of load that should be handled, thereafter, the suitable maximum outreach being determined.

To establish the values of the two parameters a horizontal straight line indicating load value is drawn from the ordinate axis until crossing point with load curve.

From this point a perpendicular line is drawn on to the abscise section with the load curve.

From this point a perpendicular line is drawn down to the abscise and the value of maximum outreach for load travel is read.

Similarly, on the reverse route we can determine the value of the load that can be handled for a given outreach; knowing the height whereto the load should be lifted, the boom length is established depending on the needed height for handling.

Lifting height is the distance measured from ground level up to the lower face of the hook. There is a load curve for each boom length.

Therefor reading of each load diagram is done as described above (figure 1).

It is to be noticed that as the booms length increase, for the same outreach, the load decreases.

The explanation is in reduction of stability degree of the crane by increasing the overturning moment.
The boom subject to study looks like in figure 2. This was done with Solid Edge (2D) soft.

3. Static study of the crane boom
The studied crane boom belongs to Liebherr truck crane presented in the figure below. To enable its Fem study, measurements on an existing model and realizing the 3D virtual model of such were needed. 
To achieve tridimensional solid model the Solid Edge ST6 programs packet for computer aided engineering was used, and after processing the physical model, the result is the model in below figure (figure 3)[3].
Static study is the method by which the static parameters of a structure (stresses, deformations, safety factor) are determined for all own modes within the interest area [4].

The next aim, by using the parameters is to build the static model of reply. In the end, it should be noted that:
- any static deformation of a structure can be represented as a weighted sum of the structure’s own mode shapes;
- each knot can be represented as a system with only one degree of freedom.

In the tables below, the following are shown: type of performed study (table 1), type of used mesh (table 2), used materials (table 3) and values of forces applied on boom (table 4).

The finite element study applied to structures is a multidisciplinary method, based upon knowledge in three fields: structures mechanics, including elasticity theory, materials strength, plasticity theory, structures dynamics, etc., mathematical analysis, including approximated methods, solving of linear algebra equation systems, own values problems, etc., and computers applied science, that deals with development and implementation of computer big programs [5].

Tis finite elements study method is used to solve some big size analytic problems.

### Table 1. Type of study performed.

| Design Objective | Single Point         |
|------------------|----------------------|
| Study Type       | Static Analysis      |
| Last Modification Date | 2/2/2020 - 6:08 AM |
| Detect and Eliminate Rigid Body Modes | No |

### Table 2. Type of used mesh.

| Avg. Element Size (fraction of model diameter) | 0.1 |
| Min. Element Size (fraction of avg. size) | 0.2 |
| Grading Factor | 1.5 |
| Max. Turn Angle | 60 deg |
| Create Curved Mesh Elements | Yes |

### Table 3. Used materials.

| Name | 1C60 |
|------|------|
| General | Mass Density | 4.51 g/cm³ |
|        | Yield Strength | 275.6 MPa |
|        | Ultimate Tensile Strength | 344.5 MPa |
| Stress | Young's Modulus | 102.81 GPa |
|        | Poisson's Ratio | 0.361 ul |
|        | Shear Modulus | 37.77 GPa |

### Table 4. Values of forces applied on boom.

| Load Type | Force |
|-----------|-------|
| Magnitude | 20000.000 N |
| Vector X  | 0.000 N   |
| Vector Y  | -20000.000 N |
| Vector Z  | 0.0     |

**Figure 3.** Crane boom assembly.
4. Case study and obtained results
The boom obtained in figure 2 was subject to study. Firstly we applied restraints (figure 4).

![Restrains establishment](image)

**Figure 4.** Restrains establishment.

We obtained the results from the figures 5 to 7:

a) Displacement’s representation (figure 5):

![Displacement’s representation](image)

**Figure 5.** Displacement’s representation.

b) Safety factor (figure 6):

![Safety factor](image)

**Figure 6.** Safety factor.
c) Von Misses stresses representation (figure 7):

![Von Misses stresses representation](image)

**Figure 7.** Von Misses stresses representation.

Further to the above presented, the following conclusions can be highlighted:
- Construction and stud of the crane boom and its components has an extremely important role in development of lifting equipment;
- Presently, there are some mathematical models for calculation of crane booms depending on their constructive version (beam with gussets and pillars, piping, etc.), and this gives the possibility of their diversity and finding optimum solutions;
- The crane model presented in this paperwork can be used on engineering and optimizing of lifting equipment, depending on a series of constructive parameters of such;
- The static stud with finite elements allows us to choose some optimum materials for an as reliable as possible operation and ensure a most long-lasting operation period possible.

5. Conclusions

In this paper, after making the 3D model, we elaborated the analysis with finite elements. Further to static study the movements of crane boom studied in this project can be noticed, and maximum travel being 59.95mm on axis, this value can be considered normal taking into account the length of crane’s mobile boom assembly, where only the boom sag without load reaches ~30mm. As to the value of 3.11 resulted safety factor, this is in range, as according to ISCIR standards this value should be among 3 - 4.5. This type of study allows us to find out which is the maximum deformation, stresses and value of safety factor borne by a technical system or a machine part being under moving or static status.

6. References

[1] Anghelache D 2014 Finite element study for box type truck crane boom in extreme lifting position under load The XX-th National Symposium on Equipment for Constructions (Bucharest, December) pp. 11-12.

[2] https://liebherrmyanmar.com/images/pdf/liebherr-mk88-mobile-construction-crane.pdf, accessed on 12.02.2021.

[3] Potîrniche A 2003 Regarding static stability of tower cranes and energetic assessment of dynamic stability The IX- the National Symposium on Equipment for Constructions (Bucharest, December, 11-12) ISBN 973-7797-30-2.

[4] Potîrniche A and Căpățână G.F. 2017 Finite element analysis of an excavator bucket embedding ripper teeth The Annals of “Dunarea de Jos” University of Galati, Fascicle XIV Mechanical Engineering 15-10 ISSN 1224 – 5615.

[5] Geisler T and Sochacki W 2011 Modelling and research into the vibrations of truck crane - Scientific Research of the Institute of Mathematics and Computer Science 1(10) pp. 49-60.