Considerations on geometric modelling and finite element analysis for a trolley travel mechanism of an overhead crane

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Abstract. Overhead cranes are complex lifting machines that have one or more mechanisms by which they perform the displacements of the loads. Overhead cranes move on high-rise ways without disturbing the activity that takes place on the ground. The trolley is one of the main components of the overhead crane and houses the wheels on which the crane moves. In this paper it was realized the 3D modelling of a trolley for an overhead crane, which was based on a real example of such a displacement mechanism and was made in the Autodesk Mechanical Desktop software. Next, the paper proposed to perform an analysis of stresses and deformations in static conditions of the trolley-type displacement mechanism under the action of its own weight. Finite element analysis was performed in Algor V23 software. This software gives the user ease in modelling but at the same time offers complete and particularly powerful analysis tools. Based on some simplifying hypotheses, a relatively simple model was obtained to analyze, but which led to obtaining results that can be a starting point for specialists in the domain of designing such equipment.

1. Introduction
The overhead crane is characterized by mounting the lifting mechanism on a trolley that can be moved along a platform, which in turn moves on a rolling track with a big gauge. Such equipments serve rectangular surfaces and can be mounted both inside buildings (workshops, halls) and outside (warehouses, construction sites). Because they do not take up space on the ground, overhead cranes are made for an extremely wide range of tasks and openings and can be used in production halls of any kind, covered or open warehouses. The design and execution of overhead cranes comply with the technical regulations in force and are equipped with all safety components applicable to this type of lifting machines [1].

General purpose overhead cranes are designed for rated loads, openings, lifting heights, classification groups, drive and operating medium according to customer requirements.

2. Theoretical considerations on overhead cranes
An overhead crane is a lifting machine equipped with a special drum used to wrap fibers that can be chains or ropes. The overhead crane can be used to lift loads as well as to make horizontal translations and move those loads from one place to another [2].

Overhead cranes use one or more mechanisms that aim to create mechanical advantages, so that can be lifted weights far beyond human capabilities. Lifting devices are very often used in the
transport industry where they load and unload goods in the industrial domain (foundries, factories with technological profile) and in the constructions domain. Most often overhead cranes are used to assemble heavy objects.

In the steel industry, every piece of steel is handled by means of overhead cranes until it leaves the factory as a finished product ready for delivery. The raw materials are poured into the furnace by the overhead cranes, the steel pieces resulting from the furnace and have high temperatures are kept cool by the overhead cranes, the finished product represented either by steel beams or thin plates made of rolls are handled with the help of overhead cranes to be stored or loaded into trucks, containers or trains [1,2].

The automotive industry uses overhead cranes to maneuver the metal frameworks of cars (the bodies).

Choosing an overhead crane suitable for a particular use is difficult, because each crane is different and the operations performed with it are different.

Overhead cranes are characterized by the fact that the load to be handled and transported only performs translational movements. They are the most suitable equipment for serving industrial halls and warehouses. They use airspace, which is usually unused. Like cranes, overhead cranes are generally electrically operated [1,2].

One of the main components of overhead cranes is the trolley - located on any side of gauge, the trolley houses the wheels on which the crane moves. The trolley transports the electric hoist over the beams along the overhead crane crossing the gauge. Figure 1 shows a trolley model for an overhead crane [3].

![Figure 1. Trolley for an overhead crane [3].](image)

3. Case study
The 3D modeling of the trolley was based on an example of such a displacement mechanism taken from the literature. Figure 2 shows the images that were used as a starting point for the three-dimensional model [4].

The dimensions of the trolley which was realized in the Autodesk Mechanical Desktop design software are 2500x2000x200 (LxLxH).
Figure 2. Pictures of the trolley used as a model [4].

For modeling were used Autodesk Mechanical Desktop software-specific generation and modification commands:

- WORKPLANES command - work plans used to be able to easily draw in coordinates;
- PROFILE A SKETCH command - the model sketch is made for each new operation;
- EXTRUSION and REVOLVE commands - are used to generate the solid;
- CUT command - used to cut and remove areas of the solid;
- TRIM, OFFSET, MIRROR, FILLET commands - used to modify and finalize the details of the three-dimensional model [5,6].

The application of all these operations resulted in the 3D model shown in figures 3 (3D model for the rolling track-trolley assembly), figure 4 (3D model of the trolley) and figure 5 (3D model of the trolley - detail in the tread wheel area).

Figure 3. 3D model for the rolling track-trolley assembly.
Next in the paper is proposed an analysis of the stresses and deformations in static conditions of the trolley-type displacement mechanism under the action of its own weight. Finite element analysis was performed in Algor V23 software. This software gives the user ease in modeling but, at the same time, offers complete and particularly powerful analysis tools.

Knowing the construction dimensions and material of the trolley, its mass was estimated at a value of 800 kg (equivalent to a force of 800 daN = 8000 N).

For the finite element analysis, the following hypotheses were adopted for the trolley:

- the material from which the trolley is made is S235, a tenacious material with linear-elastic behavior;
- the discretization was performed manually so as to be sufficiently refined taking into account the dimensions of the section (figure 6); taking this into account, is ensured a higher degree of confidence in the final results;
- the fixed type support was made on the 4 engine mounting screws on the trolley (figure 7);
- the concentrated force type was chosen so as to simulate the actual contact between the trolley rollers and the rolling track (figure 7). The chosen surface on which the force acts is the contact stain that is actually formed at the contact between the wheel and the rolling track.
In order to better observe the action mode of the forces, is presented below (figure 8) a detail of the area in which they act (contact stain area).

![Figure 8. Detail from the forces action area.](image)

Following the static analysis performed in the hypotheses presented above, the Algor software provides the user with a generous series of results, which will choose and interpret, based on experience and knowledge, those they consider suggestive for the analyzed case.

Thus, the following results were chosen for viewing:
- the tensions that develop in the trolley-type structure when this is solicited by its own weight, presented in figure 9;
- deformations of the structure, generated by previous stresses, presented in figure 11;
- displacements of the structure nodes, presented in figure 12.

In order to better observe the areas where significant tensions develop, a detail is presented in figure 10.

![Figure 9. Visualization of the trolley tensions in case of the proposed solicitation.](image)
Figure 10. Detail from the tensions area with significant values.

Figure 11. Visualization of the trolley deformations in case of the proposed solicitation.

Figure 12. Visualization of the trolley nodes displacements in case of the proposed solicitation.
The material model of the structure is that of a homogeneous, isotropic material, with linear-elastic characteristic; the linear-elastic characteristic, known as Hooke's law, which gives the linear dependence between stresses and strains is highlighted by the graph in figure 13, a graph for which were used the values for stresses and strains resulting from finite element analysis.

![Stress - deformation graphic](image)

**Figure 13.** The graphic of linear dependence of stresses as a function of deformations.

4. Conclusions

Until the appearance of the finite element method, the optimization of resistance structures in terms of material consumption was a difficult process, due to the long time that had to be allocated to the analysis of several constructive variants of the same structure, in order to discover the optimal variant.

In this context, the finite element method is a powerful working tool, given the following aspects:

- the diversity of the resistance structures geometry;
- the diversity of the boundary conditions applied to resistance structures;
- the behavior of the materials from which the structural elements are made;
- the need to evaluate as accurately as possible the states of stresses and deformations in the resistance structures, in order to achieve the optimal in terms of material consumption;

The finite element analysis performed in this paper was based on the following hypotheses:

- the type of analysis was static and proposed, according to the compound solicitation of the equipment, the evaluation of the tensions and deformations of the structure based on a theory of resistance (von Mises theory); following the analysis, given the low values obtained for the stresses in the material, compared to the permissible ones, they led to the conclusion that there is no danger of failure of the structure;
- the chosen material model is that of a homogeneous, isotropic material, with linear-elastic characteristic.
Based on the mentioned hypotheses, the analysis with finite elements was performed and this led to obtaining results that can be a starting point for specialists in the domain of designing such equipment. This study may be continued in order to improve the geometric configuration and operational performance of such equipment.

5. References

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