DETERMINATION OF THE TENSILE STRESS IN MINE HOISTING CABLES USING NUMERICAL METHODS

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Abstract: In the paper, we addressed the simulation and numerical modeling of deformation under static loading of wire ropes used in mine hoisting installations. We presented the main types of extraction vessels (cages and skips) commonly used in the mining industry, as well as the fastening devices to the hoisting rope (DLC). A review was conducted on the primary structural models of traction cables equipping mine hoisting machines. As one of the critical assessments performed on cables in mining extraction is done at maximum static load, we constructed a virtual model of a tension testing stand for a hoisting cable using SOLIDWORKS®. Essentially, we created a virtual device in the form of an assembly consisting of multiple parts, establishing geometric connections between them. Additionally, we highlighted the cable's path over the core of the fastening device. The actual tension test was performed through a simulation under static loading of a 500 mm section of the cable. We determined the von Misses stress and overall deformations of the cable section.

Keywords: extraction plant, cage, skip, balancing devices, cable

1. TRANSPORT VESSELS AND LASHING DEVICES USED IN MINE HOISTING INSTALLATIONS

1.1. Cages

Mining hoists equipped with cages are employed not only for transporting valuable mineral substances (loaded in wagons) but also for conveying personnel and materials. Figure 1 shows a non-dumping two-deck cage type 2/2, while Figure 2 illustrates the anti-runaway device used to brake the cage in case of cable breaking.

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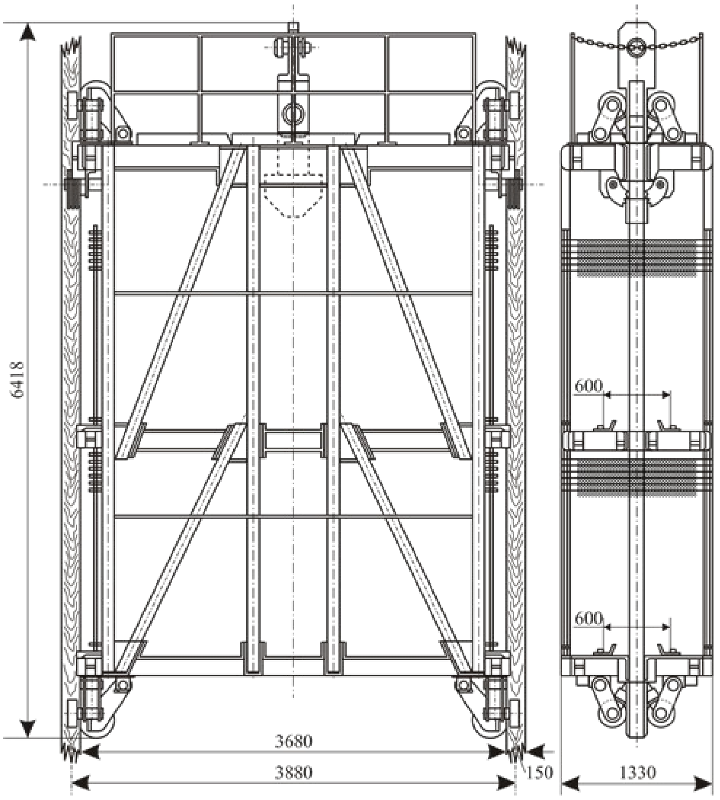


Fig.1. Double-Deck Cage

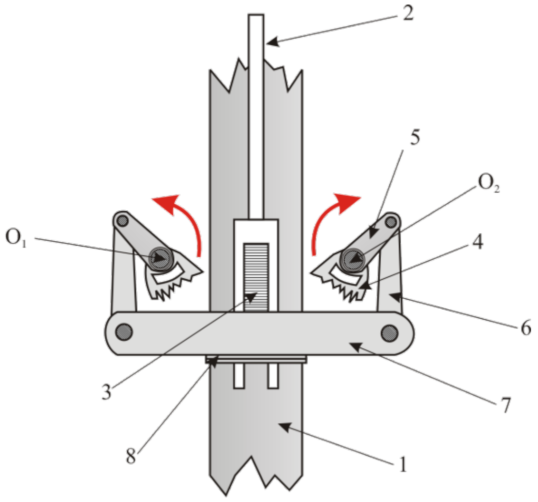


Fig. 2. Anti-Runaway Device
1 - wooden guide, 2 - suspension rod, 3 - spring,
4 - claws of the anti-runaway device,
5, 6, 7, 8 – pins

1.2. Skips

Skips are vessels used for transporting mineral substances, loaded directly from silos. In Figure 3, the constructive assembly of an 8-tonne skip is presented. It serves a mine hoist with 4 cables and is equipped with lashing and tension balancing devices for the cables.

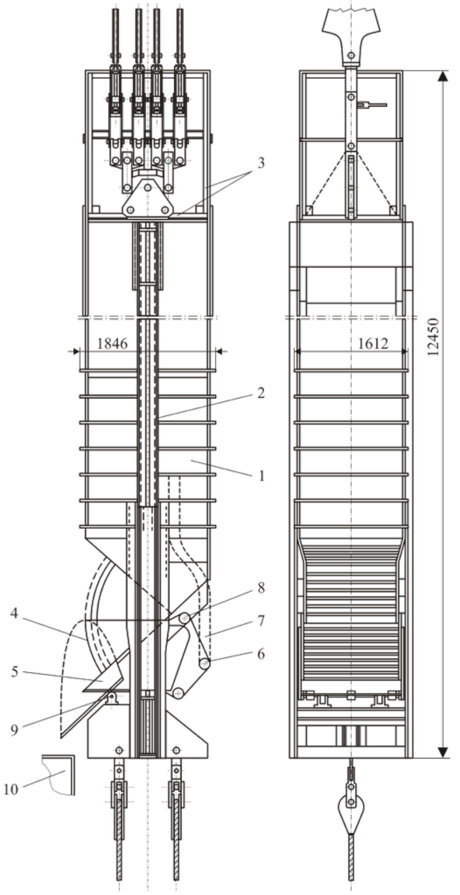
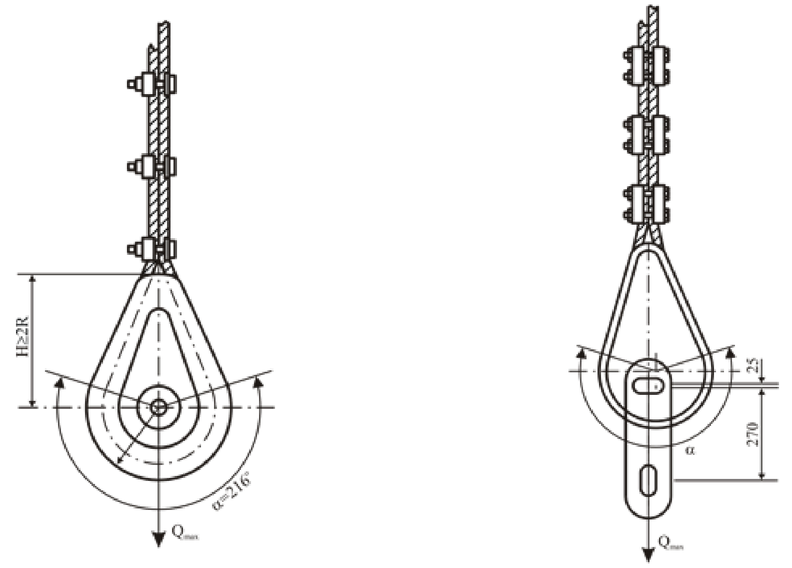


Fig. 3. Bottom Discharge Skip: 1 - box, 2 - frame, 3 - platform with railing for control, 4 - sector closure, 5 - bottom chute, 6 - roller, 7 - latch, 8 - joint, 9 - axle, 10 – silo.

1.3. Cable Lashing Devices (CLD)

Cable lashing devices ensure the secure connection of transport vessels to traction cables. The most commonly encountered cable lashing devices include loop and heart designs, as well as those with self-tightening hearts woven on one side. For small-capacity transport cages (having only one cart per level) and for skip-type transport vessels used in shaft excavation, the cable lashing device depicted in Figure 4a and 4b is employed.



a) Symmetric Heart b) Asymmetric Heart

Fig.4. Lashing Device E-169

For skip-type transport vessels, the lashing device used is the self-tightening loop and heart device depicted in Figure 5. This reduces the length of the immobilized cable, allowing for cable inspection by taking samples from inside the device.

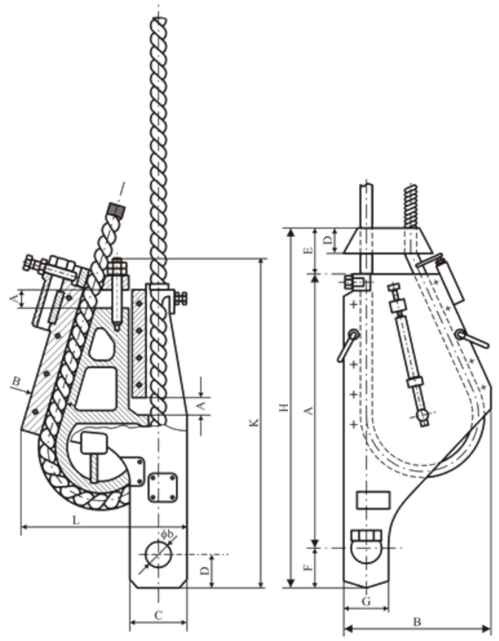


Fig.5. Self-Tightening Lashing Device

2. TRACTION CABLES, CONSTRUCTIVE SOLUTIONS

Cables constitute a structural component of extraction plants, intended for suspending extraction vessels through which transportation in shafts is facilitated. Round-section extraction cables (Figure 6) are predominantly used as actual extraction cables or guiding cables.

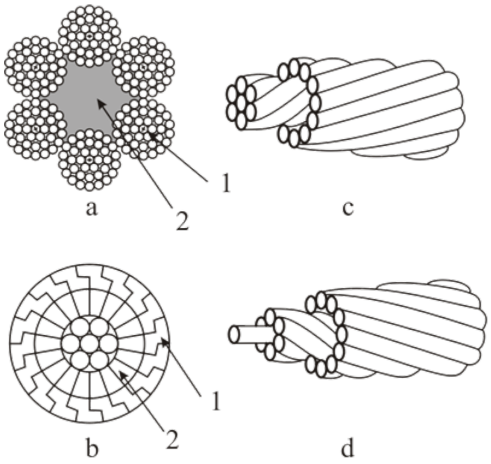


Fig.6. Round Cable

3. DETERMINATION OF STRESSES ON AN EXTRACTION CABLE UNDER STATIC FORCE USING SOLIDWORKS® APPLICATION

3.1. Assembly Presentation

We have constructed a cable lashing device (CLD) with loop and heart, similar to the one in Figure 7.

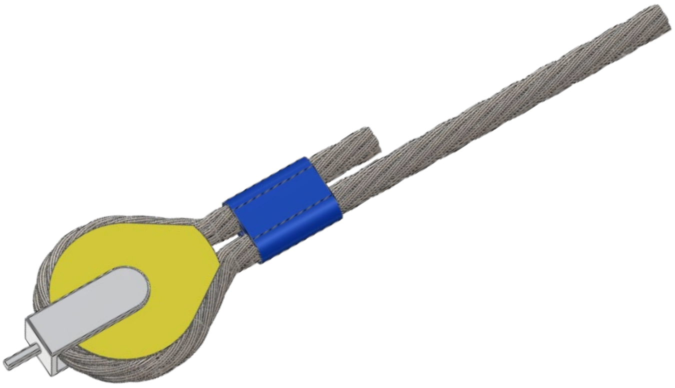


Fig.7. Assembly of the Cable Lashing Device (CLD)

The traction cable, shaped in a loop, is wrapped around a symmetrical metallic heart. The free end of the cable is secured to the suspended load with clamps. The incoming cable to this assembly is of standard construction with linear contact. It features strands formed from a single layer of wires with a diameter larger than that of the heart (Figure 8).

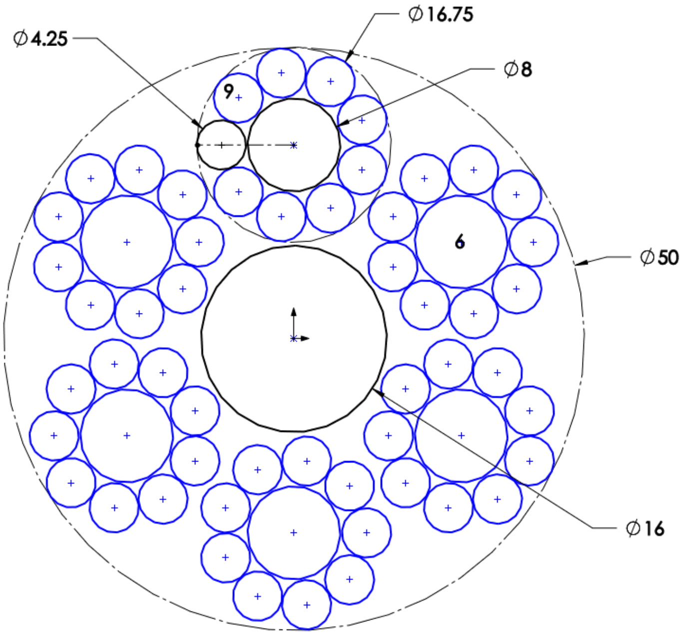


Fig.8. Characteristics of the extraction cable (cross-sectional view)

3.2. Determining the tensile stress of the traction cable

The determination of tensile stress for the cable was conducted for the model in Figure 9. The cross-sectional view of the cable is as presented in paragraph 8, and the actual generation path, this time, is a straight line with a length of 500 mm. Two cylindrical sleeves were created at the ends of the cable, serving as fixtures for one end of the cable and as the point of application for the tensile force during the conducted static simulation. The constructive dimensions of the model are depicted in Figure 10.

Fig.9. The model subjected to analysis

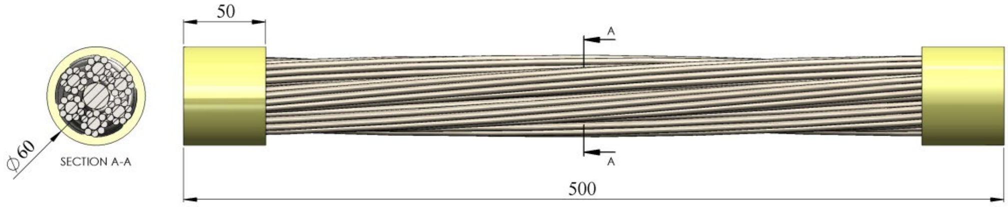
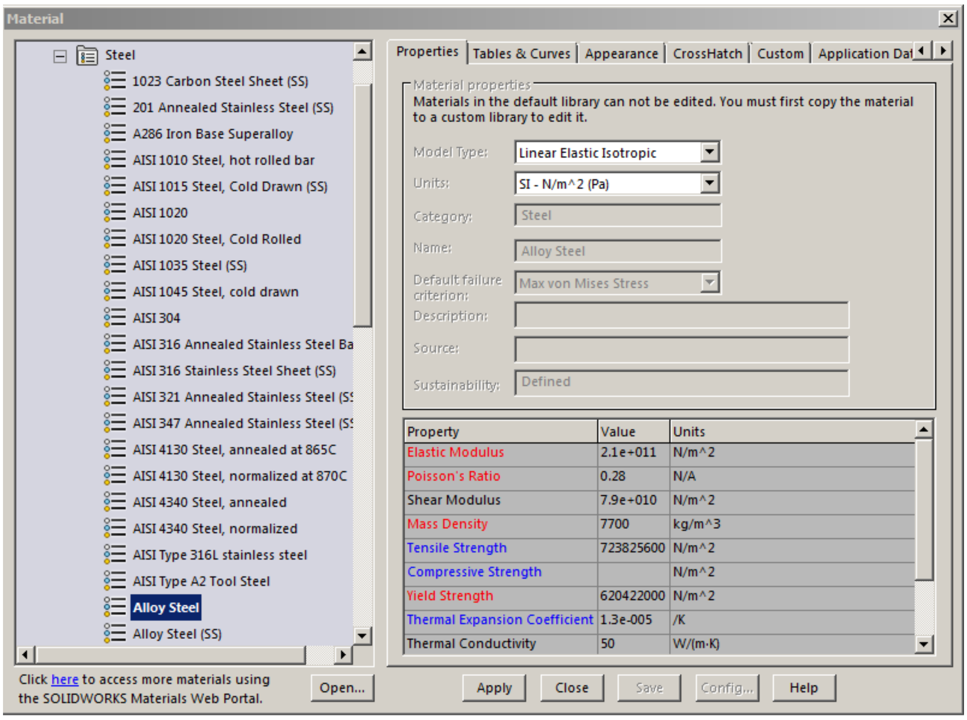


Fig.10. Constructive dimensions of the model

Determinations were performed using the SOLIDWORKS application with the `Simulation` menu and the `Static` option. Initially, as shown in Figure 11, the material from which the model is made was defined.



Material properties

Materials in the default library can not be edited. You must first copy the material to a custom library to edit it.

Model Type: Linear Elastic Isotropic
Units: SI - N/m^2 (Pa)
Category: Steel
Name: Alloy Steel
Default failure criterion: Max von Mises Stress
Description:
Source:
Sustainability: Defined

Property	Value	Units
Elastic Modulus	2.1e+011	N/m^2
Poisson's Ratio	0.28	N/A
Shear Modulus	7.9e+010	N/m^2
Mass Density	7700	kg/m^3
Tensile Strength	723825600	N/m^2
Compressive Strength		N/m^2
Yield Strength	620422000	N/m^2
Thermal Expansion Coefficient	1.3e-005	/K
Thermal Conductivity	50	W/(m·K)

Click here to access more materials using the SOLIDWORKS Materials Web Portal.

Fig.11. Defining the material from which the model is made

Furthermore, it was imposed that the free circular surface of one of the sleeves be fixed (Figure 12), and the force determining the tensile stress of the cable to act on the free circular surface of the other sleeve (Figure 13). This force is uniformly distributed on the surface and has a value of 50,000 N, corresponding to a suspended load of approximately 5 tons.

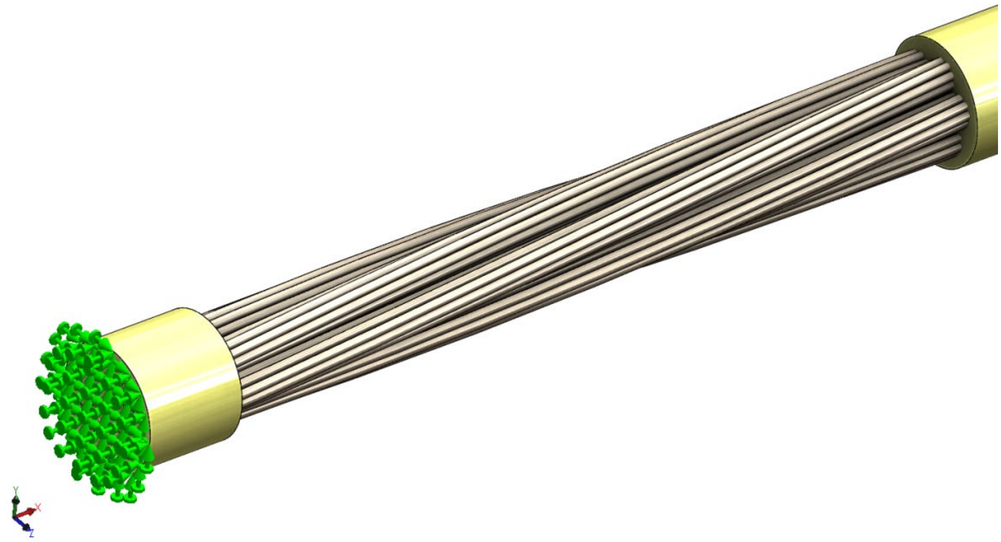


Fig.12. Fixation of the model

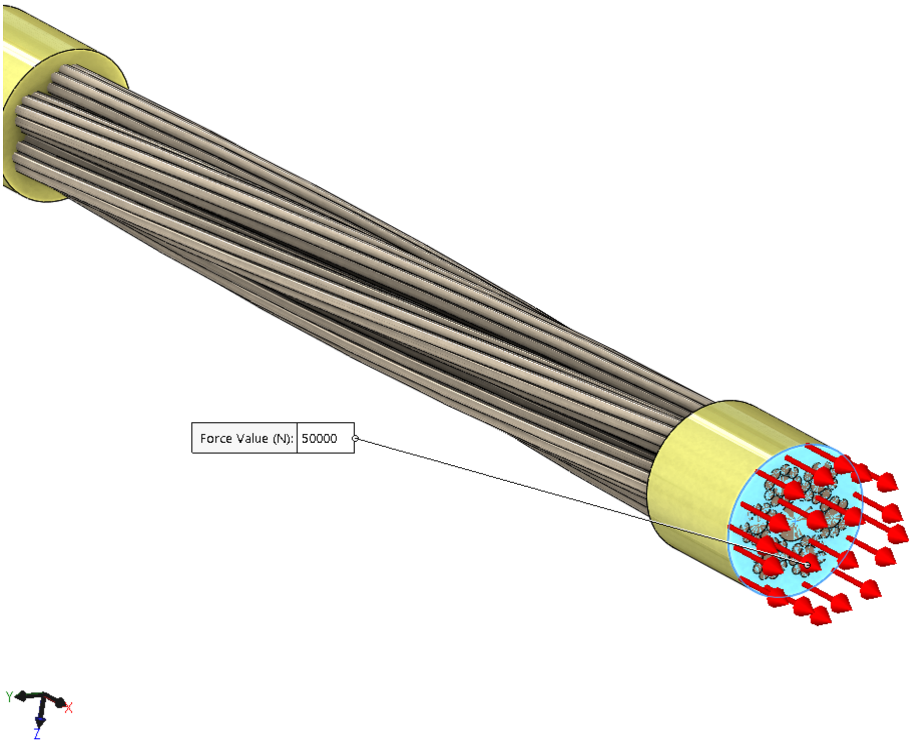

Force Value (N): 50000

Fig.13. Application of uniformly distributed force

Subsequently, the model was discretized to generate the finite elements that form the basis of the calculations. The finite element mesh generated is presented in Figure 14.

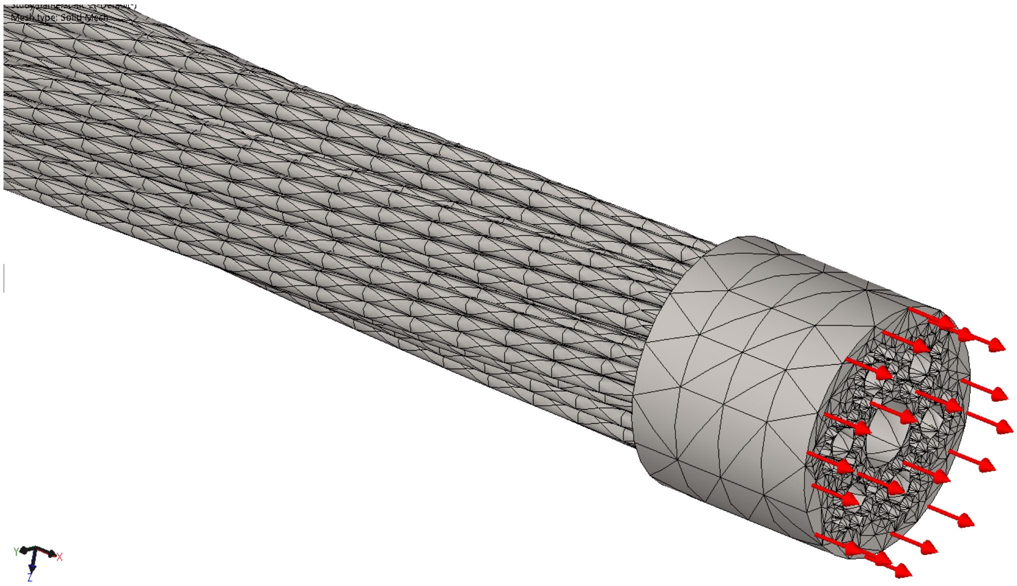


Fig.14. Finite element mesh

After performing the calculations, results were obtained regarding the tension in the cable and its deformations. In Figure 15, an overall view of the von Mises stress in the cable is presented.

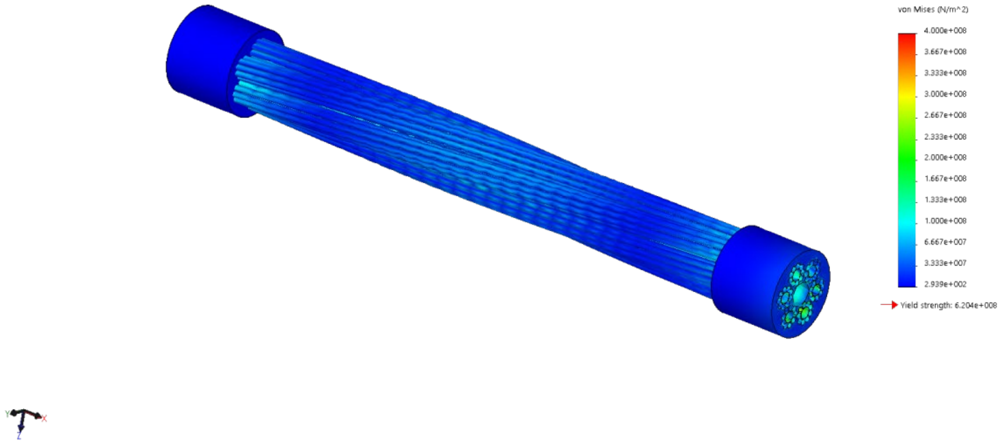


Fig.15. Von Mises stress – overview image

Figure 16 highlights the von Misses stress in a cross-sectional view at the midpoint of the cable length.

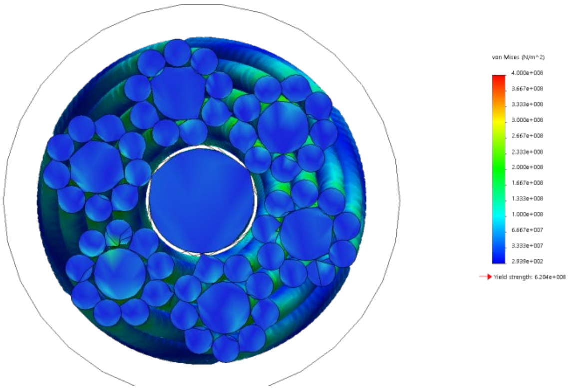


Fig.16. Von Mises stress in cross-section at half cable length

The overall deformation of the cable is shown in Figure 17, while the deformation in the cross-section at the midpoint of the cable is depicted in Figure 18.

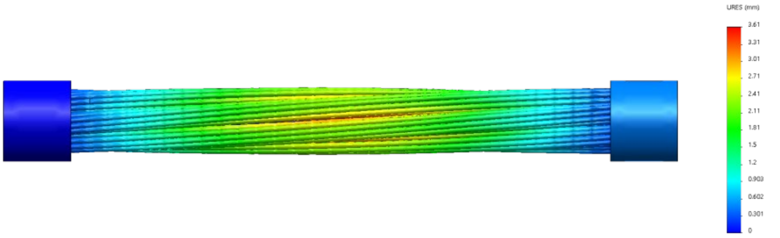


Fig.17. Global deformation of the cable

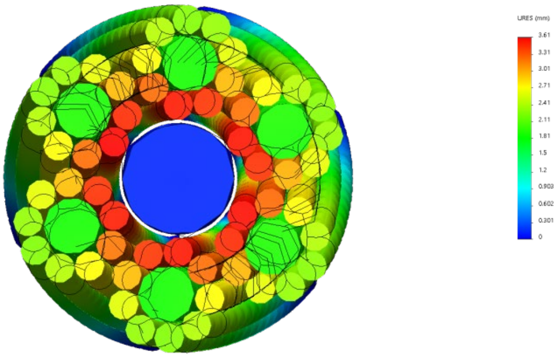


Fig.18. Deformation in cross-section at half cable length

In Figures 19, 20, and 21, the deformations of the cable are presented for the X, Y, and Z directions.

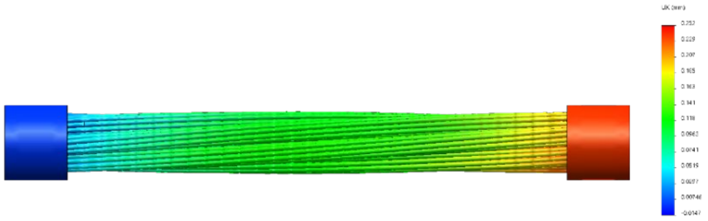


Fig.19. Cable deformation in the X direction

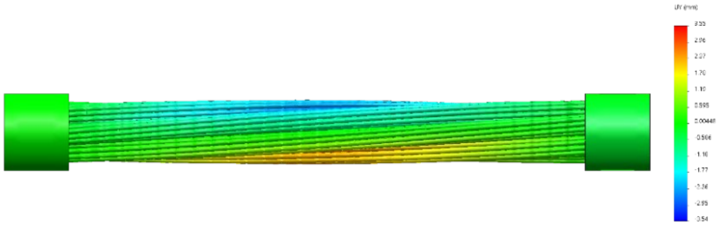


Fig.20. Cable deformation in the Y direction

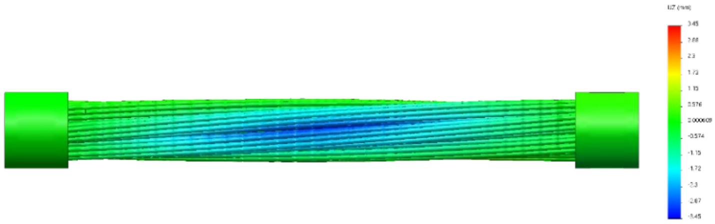


Fig.21. Cable deformation in the X direction

CONCLUSIONS

In this paper, we addressed the simulation and numerical modeling of deformation under static tensile loading of cables used in extraction plants. We began by presenting the main classification criteria for mining extraction installations and the types of extraction machines, highlighting their advantages and disadvantages.

Building upon the presented theoretical concepts, we constructed a cable lashing device (CLD) with a metallic heart, where the traction cable takes the form of a loop and is wrapped around a symmetrical heart. The free end of the cable is fastened to the suspended load with clamps.Considering that one of the crucial checks for cables in mining extraction installations is under maximum static load, we created a virtual model of a tension testing stand for an extraction cable using SOLIDWORKS®. The determination of tensile stress was performed for a cable with a standard linear contact construction and a length of 500 mm.

Cylindrical sleeves were introduced at the cable ends, serving to fix one end and as the point of application for the tensile force in the static simulation. We calculated the von Mises stress appearing in the cable structure when subjected to a tensile force of 50,000 N, corresponding to a suspended load of 5 tons. The von Mises stress did not exceed the yield stress of the material from which the cable was constructed (alloy steel). Additionally, we computed the global deformations of the cable and the deformations corresponding to the coordinate axes. These analyses contributed to evaluating the structural behavior of the cable under static loading conditions, ensuring its safety and efficiency in mining extraction installations.

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