Analysis of the dependence of the stressed state of the tracked track of a career excavator from an angle slope

Maxim Rakhutin[1], *Navarrete* Simba[1], *and Sergey* Khoroshavin[2]

[1]National Research Technological University "MISiS", 119049, Leninsky Prospekt, 4, Moscow, Russia
[2]Ural State Mining University, 620144, Kuibyshev st., 30, Yekaterinburg, Russia

Abstract. Conducted static research and determined the strength characteristics of the loaded three-dimensional model of the caterpillar track when working at different slope angles. The parameters were calculated in the 3D modeling system "SolidWorks". As a result of research, it was found that with an increase in the slope angle, the values of the static equivalent stress and strain in the caterpillar track increase in direct proportion, while the value of the safety factor decreases accordingly.

1 Introduction

Mining excavators of various carrying capacities are the main mining equipment in quarries in the development of almost all types of minerals [1].

The experience of intensive exploitation of mining excavators in various mining and geological conditions has revealed a problem - track track wear is quite fast compared to the life of the entire machine [2]. One of the reasons leading to this is abrasive wear caused by the operation of elements in an abrasive medium, another reason is associated with fatigue failure of the surface during operation under variable load. To calculate the fatigue strength, it was necessary to conduct studies to determine the influence of operating conditions, in particular, the slope angle.

Failures in the running equipment, including those related to caterpillar track breakdowns, lead to downtime of excavators, therefore the prevention and prediction of this failure, resource assessment, is an urgent task, which was devoted to a number of works.

When digging and moving a hydraulic caterpillar excavator, the tracks of the caterpillar chain are constantly exposed to variable loads, when the stresses caused by them exceed the mechanical strength of the metal, cracks and breaks occur in it and, as a result, deformation of the treadmills and breakage of the holes for the fingers. Factors that accelerate wear are speed, weight and power of the machine, shock loads, abrasive impact, track width, track chain tension. When the crawler wheels move, the outer surface of the rectangular base of the track and the lugs are pressed to the ground and loads on the tracks of the tracks are created. In this case, maximum stresses arise in the areas of transition from the maximum to the minimum height of the tracked track. Even greater pressure on the caterpillar track occurs when digging. Compared with the average specific pressure when moving, the maximum pressure on the caterpillar track when digging along the track increases by 4-4.5 times. When digging at an angle (the turntable is installed so that the projection of the longitudinal axis of the excavator passes through the tension wheel), the maximum pressure increases by 7-12 times.

So in [3] the effect of track tension on fatigue life was studied, in [4,5] the causes of failure of the tracks of a bucket wheel excavator during its driving were analyzed, the main causes were micro- and macrocracks, deviations of the material properties of the tracks from the claimed ones - i.e. . defects in their production; in [6], brittle fracture, also caused by production defects, was called the cause of failures.

At the same time, in works devoted to the reliability of tracks, such a factor as the angle of inclination of the excavator was not taken into account, although the magnitude of the load acting on the track at different angles of inclination can differ several times.

Analysis of the stress state of the caterpillar track of mining excavators depending on the slope angle will make it possible to more accurately select their optimal shape and predict the resource.

2 Materials and Methods

The article considers the analysis of the stress state of a caterpillar track using modeling in the SolidWorks program [7] using the example of a P&H 4100-XPC mining excavator [8].

3 Results and Discussion

In the beginning, according to the available drawings of the caterpillar track, a section consisting of three caterpillar tracks and one track roller was selected, where the middle track track contacts the track surface with the track roller and on the lower bases of the tracks with a flat surface. Next, his three-dimensional model was built (Fig. 1).

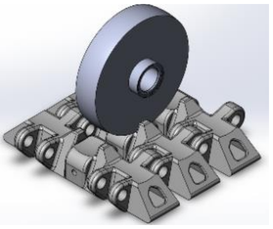

Fig. 1. The investigated three-dimensional model of the selected track section in SolidWorks.

Using the SolidWorks simulation application, a static analysis of the three-dimensional model under study was performed at various slope angles α (Fig. 2).

Based on the parameters of the excavator under consideration, it was calculated that a load of 830000 N acts on the track roller [9], which is part of the total weight of the excavator.

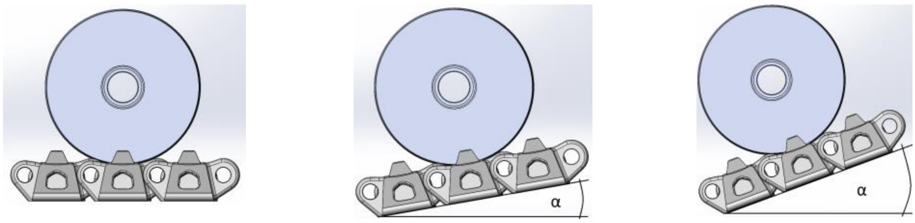

Fig. 2. Three-dimensional model of the track section at various slope angles α: a) α =0º; b) α =10º; c) α =20º.

As a result of performing a static analysis, SolidWorks simulation defines diagrams for the following strength characteristics of a loaded model:

a) Equivalent voltage (Fig. 3), expressed in MPa and not having a direction. It is a value calculated based on the values of the main stresses at each point of tracks. The resulting plot provides enough information to assess its reliability.

Plots of the equivalent stress of the model under study show that its design experiences the maximum stress state in the contact zone of the rink and the caterpillar track, and depending on the slope angle, its value ranges from 16.75 to 78.48 MPa.

b) Static displacement (Fig. 4), showing the direction and magnitude of the displacement of each point in the design of the studied model under the influence of a given static load.

The obtained values of static displacement at each slope angle range from 0.013 to 0.041 mm.

c) Distribution of safety factor (Fig. 5), showing at each point in the design of caterpillar tracks the corresponding values of safety factor.

The diagram of the distribution of the safety factor makes it possible to identify which zones in the structure are weak under given conditions.

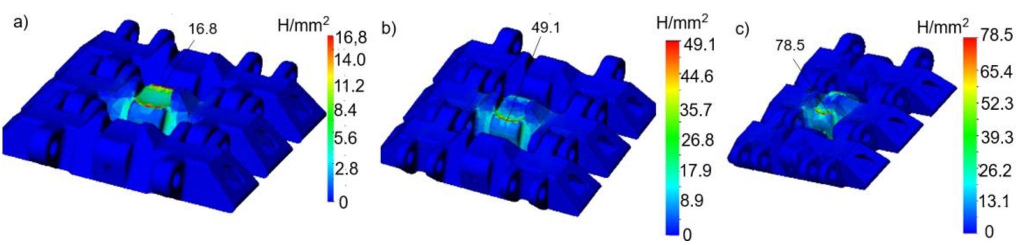

Fig. 3. Plots of static equivalent voltage of the investigated model at tilt angles: a) α =0º; b) α =10º; c) α =20º.

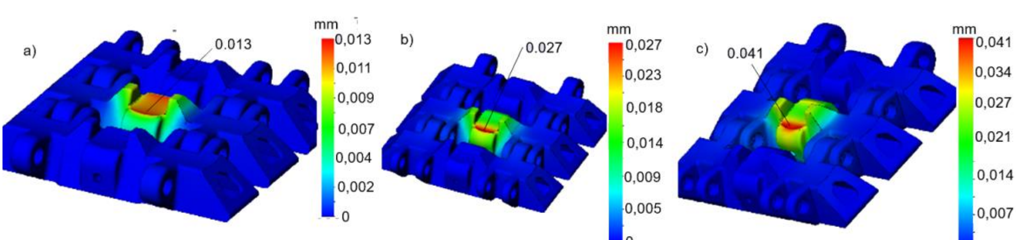

Fig. 4. Plots of displacements at tilt angles: a) α =0º; б) α =10º; в) α =20º.

Table 1. The results of a static study

№	Slope, α, hail	Maximum voltage σ_{max}, MPa	Maximum movement, Δ_{max}, mm	Safety factor, k
1	0	16.85	0.013	12.94
2	10	49.1	0.027	7.18
3	20	78.48	0.041	2.5

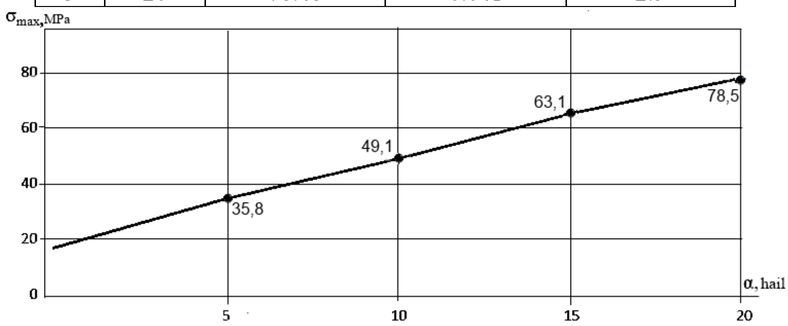

Fig. 5. The dependence of the maximum equivalent voltage on the slope

A regression analysis of the results of calculating stresses and displacements was performed, and an almost linear dependence of the parameters on the angle was revealed. The expressions for calculating stresses (1) and displacements (2) have the form:

$$\sigma_{max}=2.9\alpha+16.85 \quad (1)$$

$$\Delta_{max}=0.0014\alpha+0.013 \quad (2)$$

An important characteristic is the safety factor of the caterpillar track k, determined from expression (3).

$$k = \frac{R_C}{R_{max}} \quad (3)$$

R_C - permissible stress (yield strength); R_{max} - maximum stress.

The need to use this coefficient is due to the inaccuracy of the forecast and calculation of the existing loads, a variation in the strength characteristics of the caterpillar track, due to the large number of factors affecting the quality of the manufacturing process.

The graph of the obtained values of the safety factor from the slope angle is presented in Fig. 6.

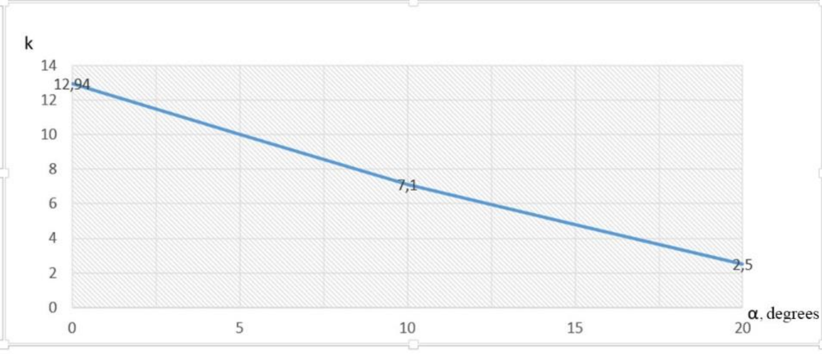

Fig. 6. A graph of the dependence of the obtained values of the safety factor on the slope.

As follows from the graph, this dependence is quadratic. With an increase in the slope angle to 20 degrees, the safety factor decreases by 5 times, and when other unfavorable factors coincide, the probability of an excavator caterpillar track failure is significantly increased.

4 Conclusion

1. With an increase in the slope angle, the equivalent stress and strain values in the caterpillar track increase in direct proportion, while the value of the safety factor decreases accordingly quadratic dependence.

2. The equivalent voltage at an angle of 20 degrees increases by 4.5 - 5 times compared with the horizontal position of the excavator.

3. With an increase in the slope angle to 20 degrees, the safety factor decreases by 5 times.

4. When designing a caterpillar track - choosing its geometric parameters, it is necessary to consider the possible tilt angles of the excavator during operation.

References

1. V.S. Kvaginidze, Yu.A. Antonov, V.B. Koretsky, N.N. Chupeykina, *Excavators in quarries. Designs, operation, calculation,* 409 (2011)
2. I.A. Orlov, Truck Track Crawler Chain Excavators, Pat. of the Russian Federation N 2646712 appl. 01.07.2016, publ. 06.04.2018
3. H. Zhao, G. Wang, H. Wang, Q. Bi, X. Li, Engineering Failure Analysis, **79**, 737-748 (2017)
4. S.M. Bošnjak, M.A. Arsić, N.D. Zrnić, Z.D. Odanović, M.D. Procedia, Engineering, **10** 2244-2249 (2011)
5. S.M. Bošnjak, D.B. Momčilović, Z.D. Petković, M.P. Pantelić, N.B. Gnjatović, Engineering Failure Analysis, **35,** 462-469 (2013)
6. Z. Yu, X. Xu, X. Mu, Engineering Failure Analysis, **17,** 1102 -1109 (2010)
7. V.P. Prokhorenko, *SolidWorks A practical guide* Press, 448 (2004)
8. P&H Mining Equipment, Inc., *Operator Manual 4100-HRS*, 393 (2014)
9. V.G. Dmitrienko, E.G. Shemetov, N.V. Simba, Mining Equipment and Electromechanics, **4**, 10-14 (2019)