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Substantiating Ways of Load Application When Modeling Interaction of a Multiincisal Mining Machine Actuator With Rocks

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Abstract: two methods of modeling of interaction between a mining machine working body and rocks are considered; a multi-cutter working body sum impact on rock stress-strain state in a cutter action zone is described; practicability of distributed forces application in math modeling is substantiated.

1. Introduction

Currently geokhods of a new generation are being designed [1]; a specific principle of geokhod operation requires a special working body (WB) [2, 3] There are many different types, configurations and design concepts of WB of tunnel boring machines (TBM). To make the right choice and to determine rational parameters of mining machine WB it is necessary to evaluate the nature of interaction between the instrument and the rock face. It is clear that fabrication and testing of experimental mining machinery is costly, moreover in Russia there is no testing grounds for mining machines.

Using mathematical modeling of interaction between WB and rock face, and analysis of pictures of rock face stress-strain state (SSS) [4-8] give material for research and greatly accelerate creation of the final version of TBM.

Considering a complex nature of stresses in the rock face, it is practical to apply a method of numerical calculations, namely the Finite Element Method (FEM) for math modeling.

Results and Discussion

When modeling interaction between a multi-cutter tool and a face, a force, simulating interaction between rock and each cutter, is to be applied to a model based on **cutter arrangement** and an angle of WB steer about its axis. For WBs of drum-, cutter head- or helical blade-type the FEM gives information on SSS in the rock face for one working body position (rotation angle) and one cutter arrangement.

If we represent a total WB cutting force as equivalent distributed normal and tangential forces, applied to a contact area between a tool and a face, such a force corresponds both to any position of the working body and to each cutter arrangement.

To test the applicability of such approach it is necessary to evaluate similarity of impact both of distributed forces and of a cutter set total force. For this purpose a SS states of a cylindrical rock

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sample (D = 1200 mm and a height L = 800 mm) have been modeled with various force applications. A comparative analysis of modeling results has been performed.

Figure 1 shows patterns of force application to the models.

The bottom end is fixed and forces are applied to the upper end according to 4 patterns:

1) concentrated force of one cutter in the end center (Fig. 1 b);

2) concentrated forces of a cutter set, uniformly arranged in a circle (d = 893 mm) (Fig. 1в);

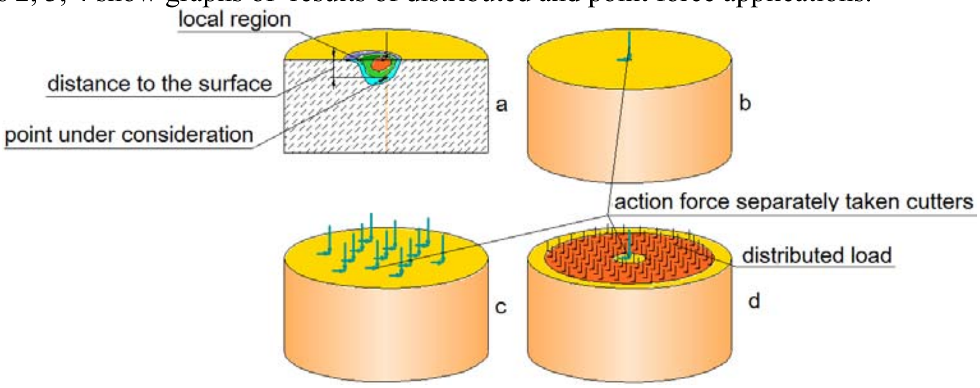
3) distributed forces in a circle with a central cutter (D / d = 893/200 mm) (Fig. 1г).

In areas of interaction between the cutter and the rock, forces (normal Pn = 10 кН and tangent Pt = 2.5 кН) and distributed forces (normal qn = 0.303 MPa and tangent qt = 0.076 MPa) are applied, which are equivalent to the total force of the corresponding set of cutters.

Principal force dependences σ_3 on a distance H in the central cutter contact zone (Fig. 1a) are determined for all force patterns.

Table 1 shows results of numerical modeling. Table 2 shows pictures of SSS in the cutter area.

Figures 2, 3, 4 show graphs of results of distributed and point force applications.



a) location of the area considered, b) one central cutter, c) uniformly distributed cutter set, d) central cutter force and distributed forces

Figure 1 - Patterns of total force applications

Table 1 – Results of SSS numerical modeling in a local area

H (mm)	Minimum values of principal forces σ_3 at a distance H from the surface in central cutter contact area (MPa)					
	σ_{3i}	$\sigma_{3\Sigma}$	$\delta\sigma_{3\Sigma}$	σ_{3iq}	$\delta\sigma_{3iq}$	σ_{3q}
0	-7.275	-7.335	-0.060	-7.341	-0.066	-0.070
1	-5.748	-5.795	-0.047	-5.802	-0.054	-0.056
2	-4.737	-4.785	-0.048	-4.791	-0.054	-0.053
4	-3.076	-3.117	-0.041	-3.122	-0.046	-0.051
8	-2.121	-2.159	-0.038	-2.164	-0.043	-0.046
16	-1.157	-1.178	-0.021	-1.182	-0.025	-0.029
32	-0.408	-0.418	-0.010	-0.421	-0.013	-0.013
64	-0.134	-0.133	0.001	-0.132	0.002	0.001
100	-0.052	-0.033	0.019	-0.038	0.014	0.014
150	-0.021	0.005	0.026	0.001	0.022	0.022

H – distance depthward from the surface

σ_{3i} – one cutter force

$\sigma_{3\Sigma}$ – total force of 13 cutters

σ_{3iq} – one cutter force and distributed forces

σ_{3q} – stress of distributed forces

$\delta\sigma_{3\Sigma} = \sigma_{3\Sigma} - \sigma_{3i}$ and $\delta\sigma_{3q} = \sigma_{3iq} - \sigma_{3i}$ effect of total and distributed forces

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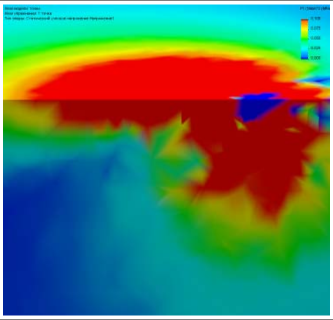
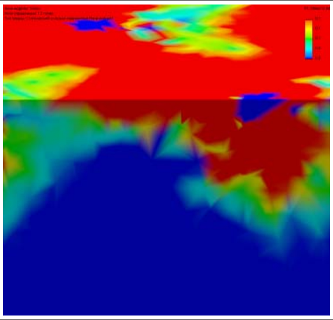
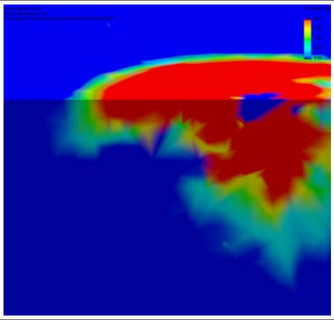
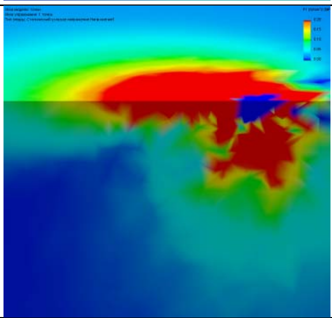
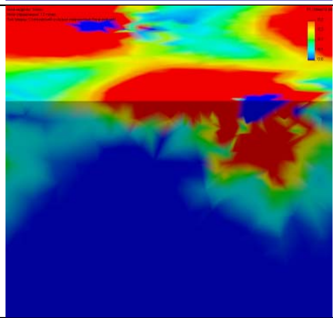
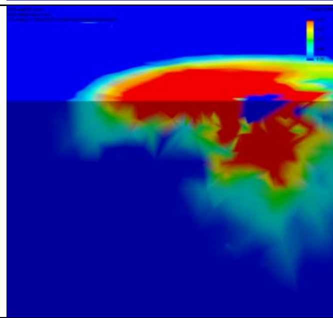
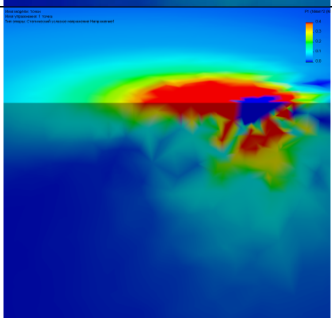
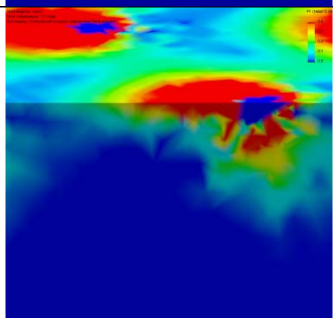
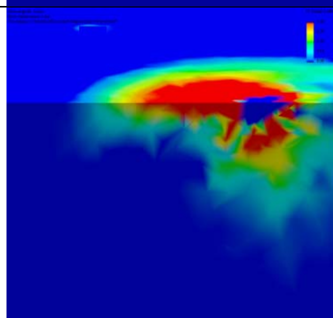
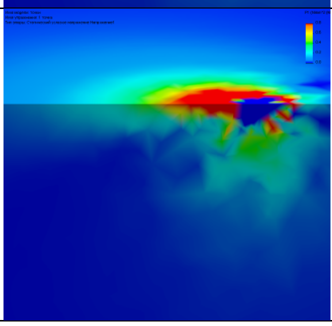
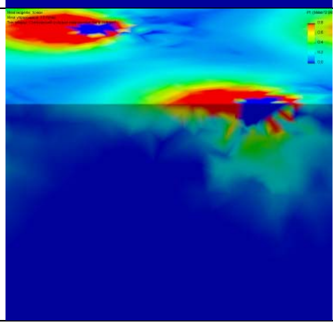
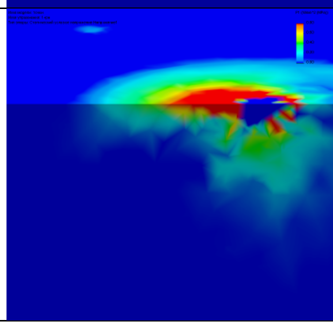
Table 2 - Pictures of principal forces σ_3 to evaluate impact of total and distributed forces on local SSS

Scale	Stress patterns		
	One blade (fig. 1 б)	Set of blades (fig. 1 в)	Distributed forces and a center blade (fig. 1 г)
0…0.1 MPa			
0…0.2 MPa			
0…0.4 MPa			
0…0.8MPa			

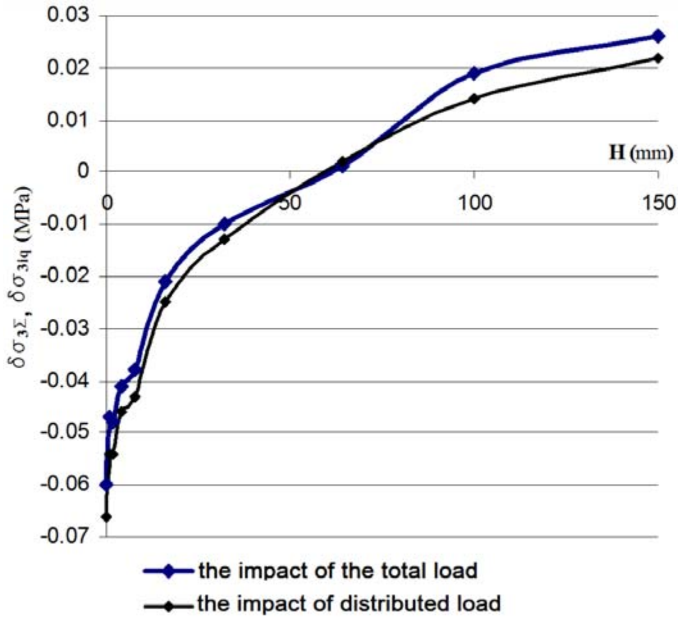


Figure 2 –Total force effect and distributed forces effect

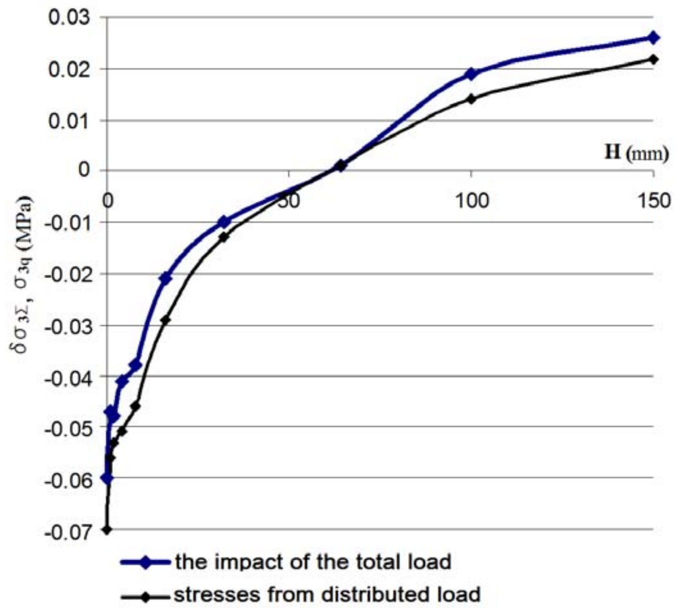


Figure 3 - Total force effect and stress of distributed forces

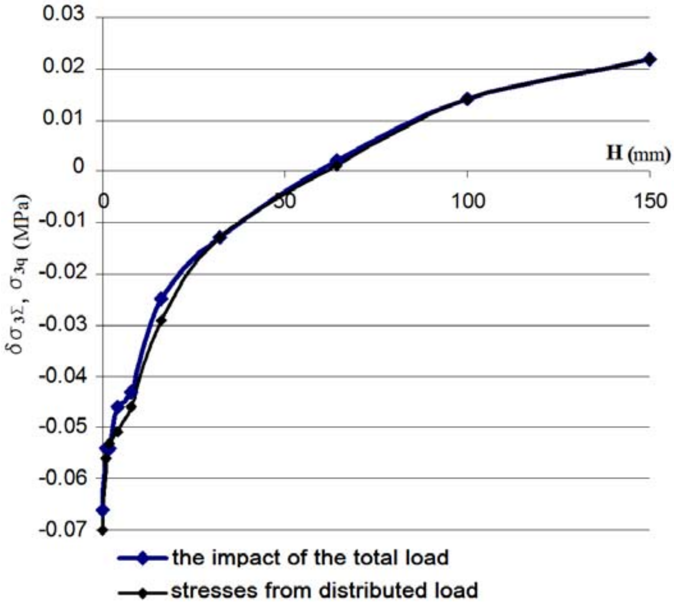


Figure 4 – Effect and stress of distributed forces

Modeling has yielded results for comparison:

1) effect of total and distributed forces on SSS in the central cutter contact area (Fig. 2);

2) effect of total force with applied distributed forces (Fig. 3);

3) effect of distributed forces with its stresses (Fig. 4)

4) Results of comparison of modeling and stress distribution (Table 2) show that a total force of cutters is similar to an equivalent distributed force.

3. Conclusions

1) a distributed force is equivalent to a total force; its impact on local stresses is similar to that of the total force in value and distribution;

2) distributed forces can be a tool for mathematical modeling of interaction between the working body and the rock.

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