Modelling bucket excavation by finite element

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Abstract. Changes in geological components of the layers from lignite pits have an impact on the sustainability of the cup path elements and under the action of excavation force appear efforts leading to deformation of the entire assembly. Application of finite element method in the optimization of components leads to economic growth, to increase the reliability and durability of the studied machine parts thus the machine. It is obvious usefulness of knowledge the state of mechanical tensions that the designed piece or the assembly not to break under the action of tensions that must cope during operation. In the course of excavation work on all bucket cutting force components, the first coming into contact with the material being excavated cutting edge. Therefore in the study with finite element analysis is retained only cutting edge. To study the field of stress and strain on the cutting edge will be created geometric patterns for each type of cup this will be subject to static analysis. The geometric design retains the cutting edge shape and on this on the tooth cassette location will apply an areal force on the abutment tooth. The cutting edge real pattern is subjected to finite element study for the worst case of rock cutting by symmetrical and asymmetrical cups whose profile is different. The purpose of this paper is to determine the displacement and tensions field for both profiles considering the maximum force applied on the cutting edge and the depth of the cutting is equal with the width of the cutting edge of the tooth. It will consider the worst case when on the structure will act both the tangential force and radial force on the bucket profile. For determination of stress and strain field on the form design of cutting edge profile will apply maximum force assuming uniform distribution and on the edge surface force will apply a radial force. After geometric patterns discretization on the cutting knives and determining stress field, can be seen that at the rectangular profile appears the “clogging” phenomenon of the cutting edge and at the polygonal profile the point of application remains constant without going inside. From the finite element method done in this paper it can be concluded that the polygonal profiles made of dihedral angles are much more durable and asymmetric cups tend to have uniform tension along the entire perimeter.

1. Introduction

Solid fossil fuels are an important primary source of energy in our country's energy structure which means a share of 39%. As of national primary energy resources lignite is the only domestic primary energy carrier in terms of resources can make significant contributions to consumer demand for electricity. Processes for the extraction of lignite surface excavation technology streaming is achieved using complex excavation-transport-dump high productivity and includes the following technology: selective excavation, transport, deposition and deposition of tailings dumps lignite deposit. The first takes place in continuous flow rotor excavators, working the steps with heights of 25-30 meters.
Transport of excavated material is made with the carrier tape with a width of 1000-2250 mm, the maximum speed of 6.15 meters/second, and the transport capacity reaches 12,500 cubic meters per hour. Dump tailings dump is done with plants with flow rates between 2,500 and 12,500 cubic meters per hour discharge arm length is between 65 and 170 meters. These parameters are reflected on the sustainability of the cup shear elements and under the action of excavation efforts leading to deformation occurring whole ensemble. An optimal geometric shape of the cup knives and teeth positively influence the process of excavation and active wear items.

2. Experimental studies

From experimental measurements performed in this work it was observed the dependence of cutting force $F_{xm}$ on the depth of cut $h_{a}$ for different careers [1]. It can be observed linear dependence between these two quantities, using our case analysis (static). The interdependence of these is given in the equation (1) from below:

$$F_{x_{\text{max}}} \approx 3F_{xm} \text{ admitting } h_{o_{\text{max}}} = b$$

Were considered two cases of application for the force $F$: for $b = 130$ mm and for $b = 150$ mm. For the two average forces results the maximum values that we see in equation (2):

$$F_{x_{\text{max}}} = 3 \cdot (1230 \cdot 130) = 479700 \ [N]$$
$$F_{x_{\text{max}}} = 3 \cdot (1230 \cdot 140) = 516600 \ [N]$$

We used as force value the maximum force for the Oltețu career because of laboratory analysis it was observed that the cutting force for this area has the highest value field. For determination of stresses and strains on the cutting edge profile constructive form shall apply in maximum force, assuming uniform distribution and edge surface force will fold radial force. To achieve the analysis of the first phase will pass the mesh model, made with tetrahedral elements with 10 nodes, as in the classical cutting edge surfaces are curved surfaces.

In the second phase were considered cutting force and radial force in maintaining solid, as follows:

$$F_{x} = 86100 \ [N / \text{tooth}]$$
$$F_{r} = 30135 \ [N / \text{tooth}]$$

Cutting force will be applied on all sides where teeth are located, six in number, and the radial force will be applied only to edge face and teeth: 2, 3, 4, and 5 in clockwise. As a fixed support was considered welded joints of the port ansamblucu knife Cup, which were taken over all degrees of freedom. Models can be treated with an excavator bucket rotor cutters on ERC1499 / 30-7 CALS and modernized as we can see in the figure number 1 from below [2,3]:

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**Figure 1.** Application of boundary conditions for the classical model.

**Figure 2.** Application of boundary conditions for the modernized cup model.
Because it is considered homogeneous and isotropic medium for the components (tooth-box-knife), we use the steel material features: modulus of elasticity $E=2.1\times10^5$ [MPa], Poisson's ratio $\nu=0.29$, density $\rho=7850$ [kg/m$^3$], limit stretch stress $\sigma_s = 448$ [MPa].

Then we analyzed the geometric models considered studying in primary and stress fields in assumptions considered using static analysis. The analysis was performed in order to highlight the differences in stresses and strains for the profiles of the two models, the classical model with curvilinear profile and upgraded model with polygonal profile.

In figure 3 we determined the stress field and deformed configuration under the tangential and radial forces action.

In figure 4 from above we can see the model of bent sheet metal. It can be observed as equivalent stresses and deformation forces model developed under excavation. It can be seen as equivalent to the classical model stresses are much larger than the model sheet [4]. In reality it was shown that the number of operating hours for polygonal profiles reached approximately 4000 hours of operation and vibrations on excavators decreased.

Also it is observed the importance of dihedral angle made on the central knife, the contour having a maximum radial force due to the action of which cannot deform inward. This can highlight in figure 5 (classic model) and figure 6 (upgraded model) where the resultant displacement under the action of forces is smaller than the classic [5].
Next we studied two models of knives of an asymmetric cups one of them having a profile with a maximum on the knife (an angle $\alpha$), forming a dihedral angle and the second having a right profile with the same assumptions calculation and under the action of the same system of forces, changing only the constructive shape of contour cutting edge [6]. Using the same conditions were determined the displacement direction radial force values and equivalent stress as we can see in the figure number 7 from below:

It can be seen that if at the right profile appeared the "clogging" phenomenon of the cutting edge, polygonal profile point "A" remaining constant, without going inside as we see in figure 8.
Figure 8. The amount of displacement in the direction of radial force/tangential force on the polygonal profile.

If you follow the figures number 9 and number 10 for the two equivalents stress profiles can be observed that the right profile has maximum points and the tension at the connection planes is much higher [7]. This showed that this type of profile was more resistant than straight profile of the bucket as we can see in figures 9 and 10.

Figure 9. The equivalent stress for the right profile [8].
3. Conclusions
From the above analysis it can be concluded that the polygonal profiles made of dihedral angles are much more durable and asymmetric cups tend to have a uniform pressure along the entire perimeter. In practice it was proved that durability at the laminated sheet cups with polygonal profile having a maximum peak is much higher than other models of cutting edges.

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