Modification of a Theoretical Model for Estimation of Rock Cuttability in V-Shape Disc Cutters Considering the Edge Radius

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Abstract: A modified theoretical model was developed for estimation of rock cutting forces, acting on V-shape disc cutters taking into account the influence of cutter edge radius. Full-scale rock cutting test data presented by Balci and Tumac (2012) was used in order to validate the proposed model, showing that there was a strong correlation between the estimated rock cutting forces and the actual data. Results show that increasing the edge radius for a constant edge angle raises the cutting forces of a blunt disc cutter more than those of a sharp disc cutter. Additionally, the effect of edge radius on cutting forces diminishes with an increase in the penetration depth, in such a way that the cutting forces approach those of a sharp disc cutter. Also, an increase in the edge angle led to a non-linear rise in the cutting forces of blunt disc cutters at a constant penetration depth.

Keywords: Blunt disc cutter, penetration depth, cutting forces.

INTRODUCTION

Mechanical excavators such as full-face tunnel boring machines have been widely used in mining and civil engineering practices in recent years. When using these excavators, prior knowledge of rock cuttability is of critical importance due to the role they play in selection, design and performance prediction of the machine. Therefore, many theoretical and empirical models have been suggested by researchers. In laboratory studies, small and large scale rock cutting tests are used for evaluating rock cuttability.

Disc cutters are amongst the most commonly used cutting tools in hard to very hard rock conditions. A look into the existing comprehensive literature reveals that the rock cuttability, cutting forces and specific energy have been widely investigated by many researchers. Rad (1975) proposed a technique for determining bluntness and wear of rolling disk cutters, making successive measurements of cutter diameter during cutting experiments and comparing them with the original cutter diameter. Roxborough and Phillips (1975) developed a mathematical model, supported by experimental data, which was found to provide a good description of the magnitude and variation of thrust and rolling forces with V-shaped disc diameter, edge angle and penetration. Afterward, Bigin (1997) updated this model considering the edge radius of the disc cutter.

In the present study, the Roxborough and Phillip's model (1975) is modified to consider the effect of cutter edge radius for prediction of cutting forces. The findings are validated using an empirical model suggested by Balci and Tumac (2012)**.**

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METHODS

A theoretical model is developed to include the edge radius of a blunt V-shaped disc cutter. The full-scale rock cutting test data presented by Balci and Tumac (2012) have been used in order to validate the proposed model, with a 99% interval confidence t-test. In Fig. 1 the geometry of a blunt V-shaped disc cutter is shown with an edge radius of r.
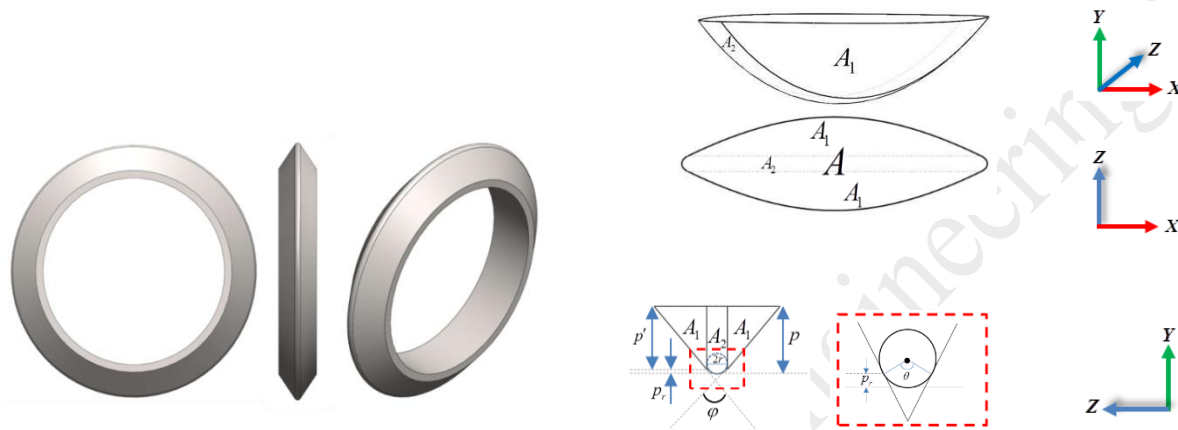

Figure 1. **The geometry of a V-shaped disc cutter with an edge radius of r**

FINDINGS AND ARGUMENT

The Roxborough and Phillips (1975) equations for prediction of the cutting and rolling forces are modified as Eq. 1:

$$F_{N,R_B} = 1.213 F_{N,R_{Rox}} \cdot e^{\frac{0.337r}{p}} \qquad r > 0 \tag{1}$$

where,

F_{N,R_B}: normal and rolling forces for a blunt V-shaped disc cutter

$F_{N,R_{Rox}}$: normal and rolling forces from Roxborough and Phillips (1975)

r: radius of a blunt disc cutter

p: depth of penetration

To study the effect of edge radius in V-shape disc cutters, the proposed model was used. Results showed that there was a strong correlation between the estimated rock cutting forces and the actual data as shown in Fig. 2.

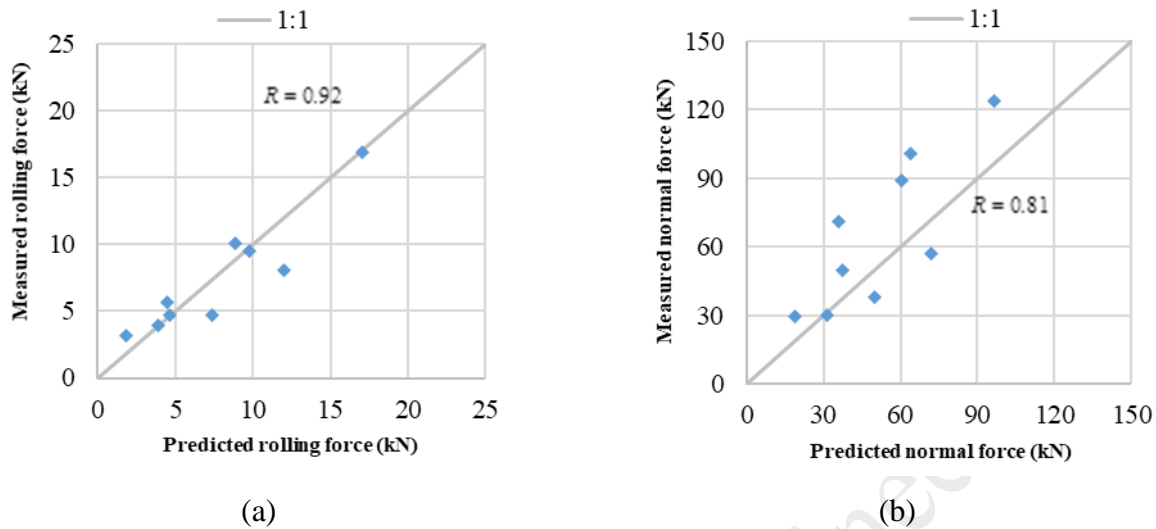(a)   (b)

Fig. 2. Cutting forces obtained from the proposed equation compared to actual data

Results of sensitivity analysis showed that for a constant edge angle, a rise in the edge radius increased the cutting forces of a blunt disc cutter more than those of a sharp disc cutter. Also, with an increase in the penetration depth, the effect of edge radius on cutting forces declined in such a way that the cutting forces approached those of a sharp disc cutter. On the other hand, increasing the edge angle led to a non-linear rise in the cutting forces of a blunt disc cutter at a constant penetration depth.

CONCLUSIONS

In this study, a theoretical model for evaluating the cutting forces of blunt V-shaped disc cutters was proposed. To check the validity of the model thecutting forces obtained from the proposed model were compared with those from empirical model suggested by Balci and Tumac (2012). The developed model showed a very good consistency. Results of the model sensitivity analysis showed that with an increase in the depth of penetration, the impact of cutter edge radius decreased. Also, a rise in the cutter edge angle raised the cutting forces in a nonlinear way. Findings of the present study revealed that the cuttability assessment was dependent on cutter geometry parameters such as edge radius of V-shaped tools realized in blunt disc cutters.

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