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Coal fragment size model in cutting process

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ABSTRACT

The size of coal fragment cutoffs by cutting mechanisms is an important index of coal mining. The larger the coal fragments, the less the dust, the lower the specific energy consumption and the higher the benefit. Therefore, a coal fragment size model was formulated in order to obtain large coal fragments in the cutting process, which considered the effect of pick arrangements (sequence and Punnett-square), helix angle, advancing velocity and the cutting line space of cutting mechanisms. Moreover, the effect of the above parameters on the size of coal fragments was analyzed in theory, which was validated by the cutting experiments correspondingly conducted using 8 different helix drums. The theoretical and experimental results indicate that the coal fragment cutoffs by Punnett-square drums are larger in size and more uniform in size distribution than by sequence drums; the size of coal fragments, increasing with the advancing velocity and the cutting line space, is almost unaffected by helix angle; the effect of advancing velocity and the cutting line space for Punnett-square arrangement is greater; the effect of cutting line space on coal fragment mass percentage below 1 cm is greater than that of advancing velocity.

1. Introduction

Coal has been regarded as the most widely used fuel because of the increases in oil price recently, which is expected to be prolonged over decades. The shearer drums and the cutting heads of road-header are the main components in the coal mining process, which consume 80%–90% power of the entire shearer and road-header, shown in Fig. 1. Different structures of cutting mechanisms result in various coal cutting performance (tool wear [1] and cutting load [2–5]), coal loading performance [6,7] and fragmentation mechanism [8,9].

Picks (Fig. 1), interacting with coal in order and repeatedly in the real mining process, are regularly arranged on the helix drums and cutting heads. The breakout patterns are mainly related to pick arrangements. Besides pick arrangements, the main factors on breakout patterns are cutting line spacing, helix angle of drum and the maximum of cutting depth.

The breakout patterns of two different pick arrangements are shown in Fig. 2(a) and (d). As a case of study, there are two helixes and six cutting lines. In Fig. 2(a), nos. 1–6 and 7–12 show the picks on the two helixes. There are two picks on each cutting line. Similarly, nos. 1–3 and 4–6 show the picks on the two helixes in Fig. 2(d), but there is only one pick on each cutting line. The shadows in figures present the cutting square of the pick. The larger the cutting square, the larger the coal fragments.

The size of coal fragment cutoffs by cutting mechanism directly affects the dust, the cutting specific energy and the economic benefit. The structure of cutting mechanisms has been optimized to increase the size of coal fragments and decline dust in the cutting process.

Breakage functions of the continuous hammer mill model were established by Austin et al. [10,11]. The influence on the size and shape distributions of the generated dust was investigated, with the long term aim of improving dust control, which had further promoted the feasibility of utilizing AE technique dust generation [12,13]. The influence of bit spacing, cutting depth and drum speed on specific respirable dust during rock cutting was evaluated, utilizing an automated rotary coal cutting simulator (ARCCS) and synthetic rock [14–17]. Cutting tests were carried out on an established cutting test bed to analyze the relationship between the cutting force and coal compressive strength, the carbide tip diameter, and the cutting depth and study the relationships between the type of pick arrangements and the cutting lump coal percentage [18]. The breakage characteristics of low rank coals were tested in a laboratory [19].

Moreover, many scholars study the distribution of rock fragments based on a fractal theory [20]. The associated microseismicity of rock bursts is studied by using fractal geometry and damage mechanics. Based on the number–radius relation of fractals, the distributions of previously reported micoseismic event locations were examined and found to have a fractal clustering structure [21]. Three kinds of methods to predict fragmentation of rock were pointed out by Wang. One is predicting the fractal dimension of crack in the rock. The other is directly calculating the size of fragmentation by searching the possible crossed cracks. The third is by using energy dissipation during rock fracturing [22]. A

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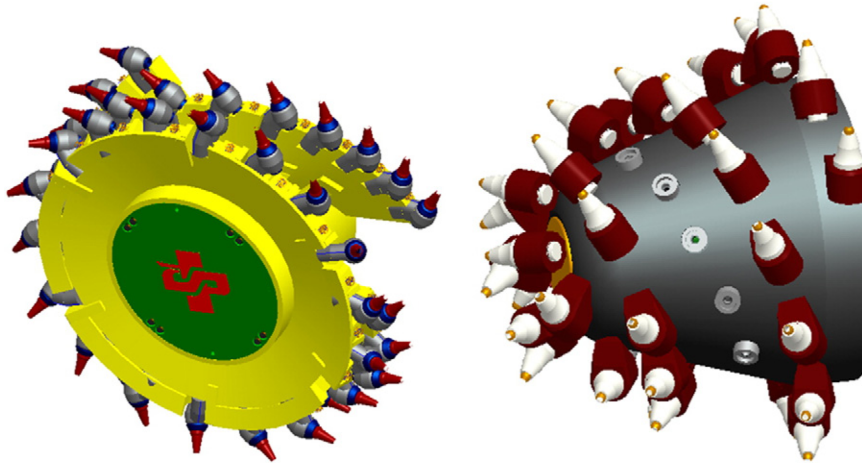

Fig. 1. Shearer drum and cutting head of road-header.

fractal model for broken cobalt crust was established after studying cobalt rich crust broken by drum-type mining head, while the theoretical formula for fractal dimension and practical calculation formula based on weighing were set up in the meantime [23].

All the researches above in order to increase the size of coal fragments, however, have not presented a proper model for coal fragment size considering the effect of pick arrangement, helix angle, advancing velocity and the cutting line space of cutting mechanism. In this paper, the coal fragment size model was established on a case study of sequence and Punnett-square drums to obtain the drum design method for large coal fragments by analyzing the effect of structure and movement parameters of drum on coal fragment size distribution.

2. Theoretical model

The cutting square is surrounded by lines I, II, III and IV. Lines I and II are caving lines, which are parallel to lines III and IV, respectively. Axes coordinate system is established with the origin at 'O_1', shown in Fig. 2. Therefore, the size of the cutting square can be calculated by Eq. (1).

$$S = l_{\mathrm{I}} \cdot l_{\mathrm{II}} \sin 2\varphi, \tag{1}$$

When $x_2 \geq x_3$ to the sequence arrangement (Fig. 2(b)), the equation of line I is

$$y = x \tan \varphi. \tag{2}$$

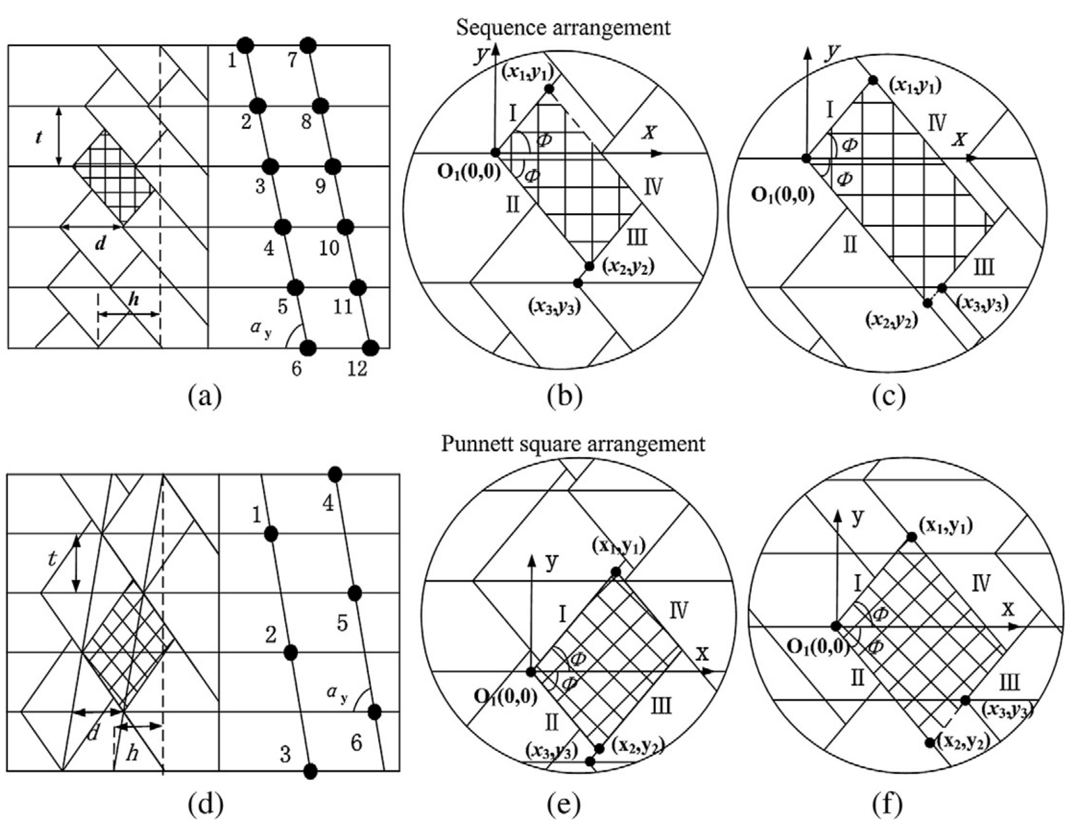

Fig. 2. Breakout patterns of two different pick arrangements.