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Parameters analysis of shearer drum loading performance

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ABSTRACT

Three drums with different helical angles (15°, 20°, and 25°) were developed to investigate improved loading performance of the shearer drum. Nine trials were performed at different drum rotation speeds (80, 100, and 120 r/min) and different haulage speeds (1.5, 2.0, and 2.5 m/min) in an orthogonal test design. Loaded coal quantity and cutting power of the drum were the responses measured under the different conditions. The effect of the parameters was determined by means of the extreme difference method. The significance of the effects was determined by analysis of variance. The results indicate that the effect from changes in the helical vane on loading performance of the drum is the largest in magnitude. The haulage speed has the least affect on loading performance. The helical angle has the least affect on cutting power of the drum. Haulage speed has the largest affect on the cutting power of the drum.

1. Introduction

Coal in thick and medium seams has been completely mined in some regions of China. The length of service of a mine may be extended and additional sustainable production may be obtained through the thin seam, or extremely thin seam, mining methods. There are three major difficulties to overcome when mining thin coal seams: reliability, adaptability, and drum loading performance. The loading performance is the overall problem and the influence of loading performance on production efficiency is the biggest. The relationship between cutting performance indicators (cutting specific energy consumption, respirable dust quantity, or cutting load) and drum parameters (structural and kinematic parameters) have been studied [1–8]. These studies propose a method of improving the cutting performance of the shearer drum. Research on the loading performance of the shearer drum is scant [9–13]. These studies indicated that the loading performance could be improved by changing the structure type and the structural parameters of the drum. The drum loading performance was influenced mainly by the helical angle of the drum [14]. Based on this previous work, relationships between drum loading performance and drum parameters like helical angle, drum rotation speed, and haulage speed are reported here to provide useful conclusions directly related to production.

2. Experimental

In order to obtain the desired relationships experiments were done using the Cutting Test-Bed for Coal & Rock [15,16]. The loading quantity and the cutting power were taken as measures of the different cutting conditions. The experimental equipment and the loading process are shown herein as Figs. 1 and 2.

The experimental cutting conditions were: a helical angle (α) of 15°, 20°, or 25°; a drum rotation speed (n) of 80, 100, or 120 r/min; and, a haulage speed (V_q) of 1.5, 2.0, or 2.5 m/min. The compressive strength of the coal analog was 1.97 MPa.

Testing expenses and testing times were reduced, and efficiency improved, by using the orthogonal test method. The helical angle, the rotation speed, and the haulage speed are the factors *A*, *B*, and *C*, respectively. Each factor could have one of three different values. The combined, complete, experimental program would have had $3^3 = 27$ trials but nine trials were done following the orthogonal test method. The factors and the orthogonal design are shown in Tables 1 and 2.

3. Results and discussion

A total of nine trials were conducted following the combinations listed in Table 2. The loaded quantity and the cutting power were measured for different helical angles and different kinematic parameters to give the results shown in Table 3.

K_i^j is the sum of the observed value of factor j at level i and the other terms are given by:

$$K=\sum_{i=1}^{9}Y_i,\ P=\frac{1}{9}K^2,\ W=\sum_{i=1}^{9}Y_i^2,\ U_A=\frac{1}{3}\sum_{i=1}^{3}(K_i^A)^2,$$
$$U_B=\frac{1}{3}\sum_{i=1}^{3}(K_i^B)^2,\ Q_C=U_C-P,\ U_C=\frac{1}{3}\sum_{i=1}^{3}(K_i^C)^2,$$
$$Q_A=U_A-P,\ Q_B=U_B-P.$$

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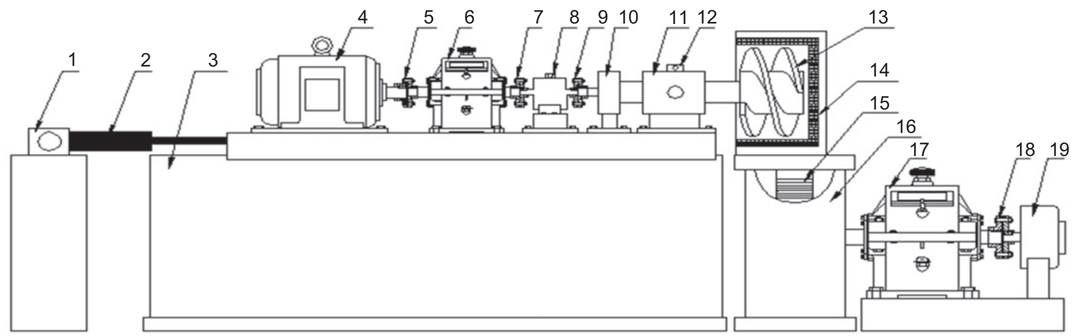

Fig. 1. Experiment principle. (1) Hydraulic cylinder bracket; (2) horizontal translation cylinder; (3) horizontal translation guideway; (4) electric motor; (5) shaft joint 1#; (6) reducer 1#; (7) shaft joint 2#; (8) torque transducer; (9) shaft joint 3#; (10) shaft block; (11) force-measuring bracket; (12) pressure transducer; (13) test drum; (14) test coal wall; (15) pinion and rack; (16) vertical translation guideway; (17) reducer 2#; (18) shaft joint 4#; (19) hydraulic motor.

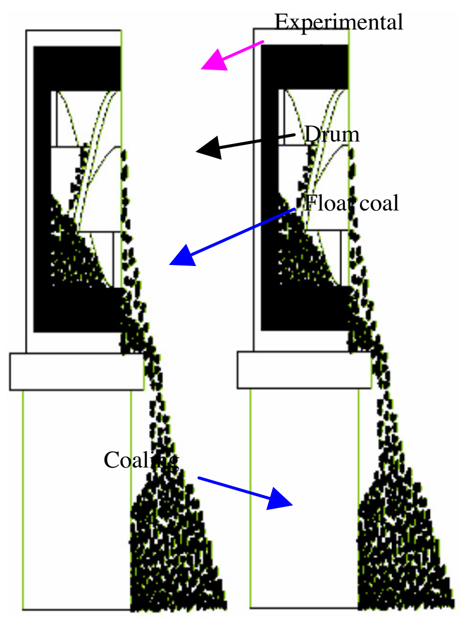

Fig. 2. Drum loading process.

Table 1
Testing factors and levels.

Level	A (α)	B (n)	C (V_q)
1	15	80	1.5
2	20	100	2.0
3	25	120	2.5

Table 2
Orthogonal test.

Index	α (°)	n (r/min)	V_q (m/min)
1	15	80	2.5
2	15	100	1.5
3	15	120	2.0
4	20	80	2.0
5	20	100	2.5
6	20	120	1.5
7	25	80	1.5
8	25	100	2.0
9	25	120	2.5

Table 3
Testing results.

Index	α (°)	n (r/min)	V_q (m/min)	H (%)	P (kW)
1	15	80	2.5	30.56	10.86
2	15	100	1.5	40.15	8.13
3	15	120	2.0	37.22	7.36
4	20	80	2.0	56.89	9.14
5	20	100	2.5	54.63	10.83
6	20	120	1.5	45.39	7.26
7	25	80	1.5	35.11	7.42
8	25	100	2.0	48.97	9.68
9	25	120	2.5	34.81	9.27

The effect of each factor on the results was found by means of the extreme difference method. An analysis of variance method appropriate for the orthogonal test was used to determine the significance of each effect [17–20]. The results are shown in Table 4.

The results for each response variable are given in Table 5. There, k_i is the mean value of level i and R is the extreme difference given by:

$$R = \max_{i \neq j}\{|k_i - k_j|\}$$

The extreme difference values, R, shown in Table 5 allow the following conclusions to be drawn:

(1) The relationship $R_\eta^A > R_\eta^B > R_\eta^C$ and related knowledge of orthogonal testing allow that the influence of each factor on the performance indicators may be reflected by the extreme difference value. This suggests that the effect of the operational parameters on drum loading efficiency falls in the order: helical angle > drum rotation speed > haulage speed. For the drum cutting power the effects fall in the order: haulage speed > drum rotation speed > helical angle.

(2) To determine which level gives the greatest effect on the response note that larger values of k_i indicate greater loading efficiency. The second level of the factor A was greater than the others since ($k_1^A < k_3^A < k_2^A$). And the highest $A_2B_2C_2$ response was obtained when $k_1^A < k_3^A < k_2^A$, $k_3^B < k_1^B < k_2^B$, and $k_3^C < k_1^C < k_2^C$. This represents a helical angle of 20°, a drum rotation speed of 100 r/min, and a haulage speed of 2.0 m/min.

However, smaller values of k_i show a smaller required cutting power. The $A_3B_3C_1$ that gave the lowest power was obtained from the relationships $k_3^A < k_1^A < k_2^A$, $k_3^B < k_1^B < k_2^B$, and $k_1^C < k_2^C < k_3^C$ to find a helical angle of 25°, a drum rotation speed of 120 r/min, and a haulage speed of 1.5 m/min. Under these conditions the cutting thickness decreases and the cutting specific energy consumption increases.