# Cutting Process Mechanics Experimental Study of Pick-cutting Coal Seams

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**Abstract.** On the base of the theoretical analysis of the rotary cutting of a single picker, a series of experiments were carried out on the cutting test bed of coal and rock to explore different forms of pick-type cutting coal seam. As such the time domain analysis was carried out on the signal of the cutting pick under different compressive strengths, the cutting thickness, the cutting cone angle, the drum speed, and the impact angle. Through the experiment, some conclusions could be capable to conclude that the cutting load changes differently under diversified circumstances. The cutting load will increase because of the growth of the compressive strength, the reduction of the drum speed, the growth of the cutting thickness, and the reduction of the cutting angle. In the process of increasing the impact angle, the cutting load will first increase and then decrease, and the corresponding impact angle is about 48° when it reaches the minimum value.

**Keywords:** pick; cutting parameters; impact angle; rotation cutting

## 1 Introduction

According to the requirements described in the working background of the shearer, by combining the relevant technology of coal and rock cutting coal seam related to the drum shearer, the dynamic characteristics of the shearer were studied during the period of coal and rock cutting by the pick, and the problems existing in the existing research were analyzed. The cutting pick of the shearer drum will be subjected to great friction and impact when cutting coal strata, which is not conducive to the normal work of the shearer. The cutting load has a significant influence on the cutting ratio consumption, cutting efficiency, dust content, stability, and reliability of the drum shearer [1~2]. Therefore, the study of cutting force has reference significance in the process of shearer drum design and manufacturing. Many relevant scholars have conducted a great many experimental studies on the cutting force of the cutter [3~4].

From a theoretical perspective, the research on a theoretical model of pick cutting and drum cutting coal and rock, a test of pick cutting homogeneous coal, a test of pick cutting coal seam with coal-rock interface,nonlinear dynamics of pick cutting loads,


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experimental study on drum cutting coal seam at coal-rock interface and additional aspects were carried out bottomed on the cutting experiment under several different cutting parameters [5~6]. Therefore, we need to find a way to improve the rock-breaking efficiency of the cut and lessen the probability of the pick's failure. How to decrease the resistance of the pick during coal mining [7~8] must be considered. In this paper, the cutting force, the force in three orthogonal directions, and the performance of the picks load are researched. The results show that uniaxial compressive strength, pick-tip cone angle, cutting thickness, drum speed, and impact angle of the shearer is related to the measured operating performance of the shearer [9~11].

## 2 Introduction of a test system for cutting coal seams

The experiments were carried out on the cutting test-bed of coal and rock (CTCR) (shown in Figure.1, Figure. 2), set the rotation velocity n(r/s) of the pick in the range of [0, 2]; A speed value v1 (mm/s) is set at [0, 33.3], which represents the velocity of the coal strata extension shaft approaching the roller; A velocity value v2 (mm/s) is set at [0, 16.7], which represents the velocity of coal strata moving along the axis of the vertical roller. The parameters of the pick tooth are shown in Table 1.


**Fig. 1.** A cutting testbed of coal and rock

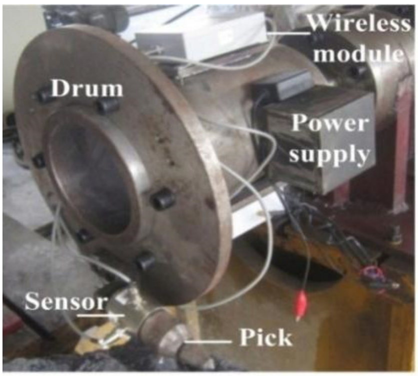


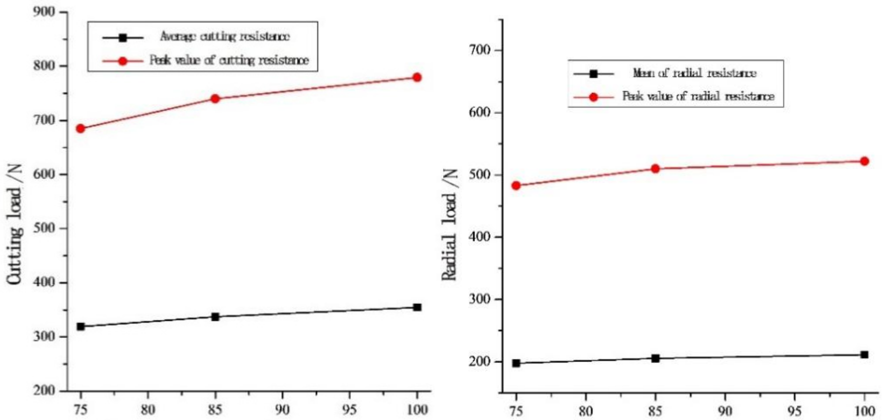

**Fig. 2.** Pick sensor and wireless data transmission module used in the experiments

**Table 1.** Structure parameters of the pick

| **Parameter** | Radius r (mm) | Vane number n (-) | Helical angle e (°) |
|---|---|---|---|
| **Value** | 280 | 1 | 75 |

# 3 Experimental study

## 3.1 Pick-tip cone angle experimental study




(a) Cutting resistance (b) Radial resistance

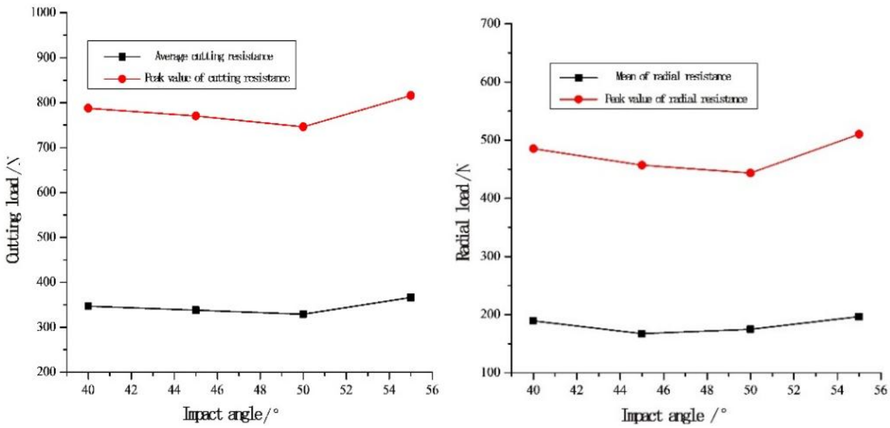
**Fig. 3.** Relationship between pick-tip cone angle and cutting load

Draw the relation curve between the cutting load and the angle of the tip of the pick, and the result is shown in Figure 3. As shown in Figure 3, the statistical values of the cutting resistance and radial resistance of a single pick are obtained by experimental studies. According to the data in the figure, we can see that the cutting resistance of the mean and peak were significantly greater than the radial resistance in the cutting process, and broken coal rock resistance is greater than the pick feed direction along the coal rock wedge resistance. It can be seen in Figure 3 that with the variation of cutting resistance, the mean peak of cutting resistance value increases with the increase of tip angle; the radial resistance trend with pick tip angle and cutting resistance are similar, indicating that increasing the angle of teeth will cause the cutting load increases. From the different angles of teeth cut cutting homogeneous seam cutting test can be seen in the load is an important factor for energy consumption, coal seam interface. To improve the efficiency of the cutting angle teeth pick can be smaller, reducing the cutting load, which to some extent reduces cutting power. In the cutting process, the angle of the cusp of the pick increases with the wear cycle. It will be dull because of the wear, and the reasonable selection and replacement of the cutting cycle is also an effective way to reduce the cutting load and improve the cutting efficiency. The friction coefficients of three kinds of cutting pick and pick tip angles of coal seam under normal circumstances are the same. But in the process of cutting, cutting pick and coal seam produce relative motion, direct wear pick, pick surface is abraded surface roughness increases greatly. The cutting pick and long-term coal seam in the process, the cutting load significantly, and rock compressive strength are proportional so that the friction coefficient and the relationship are not obvious. The results of this part of the test are in good agreement with the results obtained from the theoretical model simulation, which shows that the theoretical model has some guiding significance.

### 3.2 Impact angle experimental study

**Table 2.** Cutting load statistics under different impact angles

| Impact angle (°) | Average cutting force | Average maximum cutting force | Standard deviation | Average radial force | Mean maximum radial force | Standard deviation |
|---|---|---|---|---|---|---|
| 40 | 346.98 | 787.22 | 15.31 | 189.44 | 495.2 | 21.99 |
| 45 | 337.81 | 770.3 | 13.83 | 167.53 | 486.9 | 17.66 |
| 50 | 329.01 | 745.95 | 13.52 | 174.91 | 473.33 | 16.15 |
| 55 | 366.3 | 815.6 | 10.28 | 216.68 | 522.17 | 14.71 |

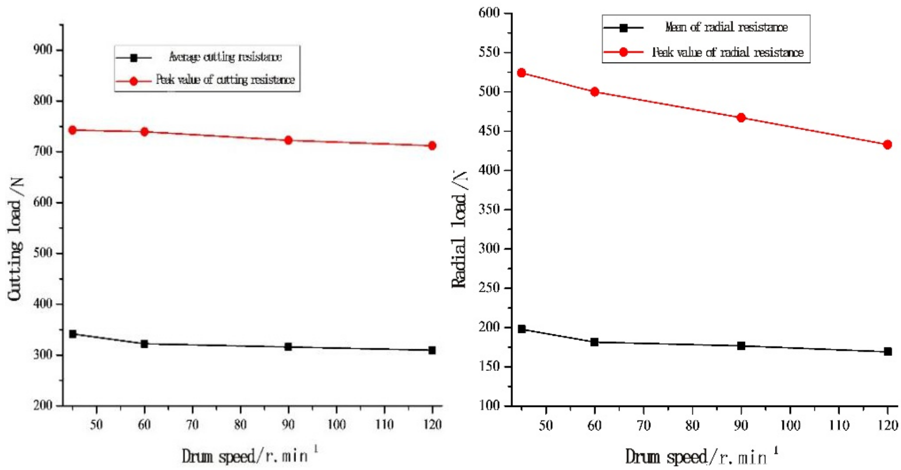



(a) Cutting resistance (b) Radial resistance

**Fig. 4.** Relationship between impact angle and cutting load

The relation curve between the cutting load and the impact angle is plotted according to the experimental data in Table 2, as shown in Figure 4. In the range of experimental studies on impact angle, the changing trend of cutting resistance, and resistance to radial peak average mean peak value with increasing impact angle decreases at first. When the impact angle to 50° after the load change is increasing, this is because the angle of teeth with pick is 85°. When the impact angle is increased to 50°, only, and the simulation results of the second chapter the theoretical model fits the reason. The second chapter is the analysis of the simulation results on cutting and cutting resistance. The mean change of cutting resistance and radial resistance is less significant, because the theoretical model of cutting load is an ideal cutting condition, without considering the caving of the cutting teeth and the contact position between the pick and the coal and rock mass. In the process of cutting, when the impact angle is large, pick, pick side behind the handle of the boss and may contact, and rock burst, contact with the coal rock surface will increase, the cutting resistance and the mean radial resistance did not change significantly. Figure 4 and Table 2 can be seen, the impact angle between 45° and 50°, cutting resistance, and radial resistance made smaller, so taking 48 degrees near the impact angle to guide the pick assembly manufacturing, has certain practical significance. In addition, it can be seen from the experiment that the simulation results of the theoretical model are in good agreement with the experimental results, so the theoretical model of the single-pick rotary cutting has certain practical significance.

### 3.3 Drum rotating speed experimental study

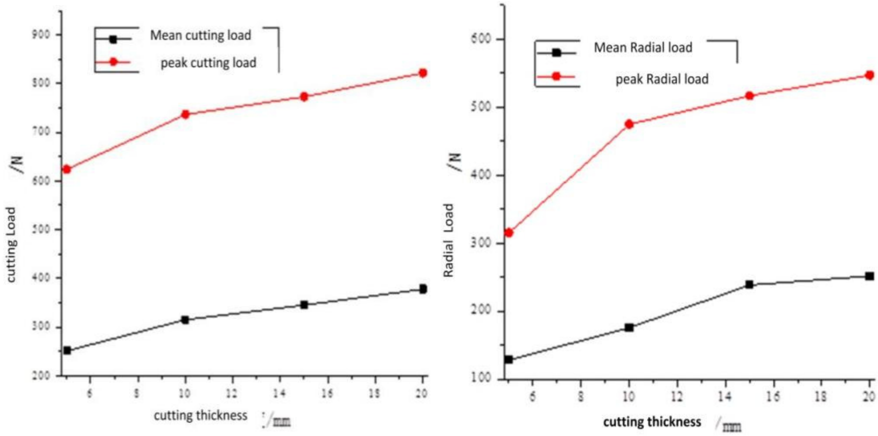



(a) Cutting resistance (b) Radial resistance

**Fig. 5.** Relationship between drum rotating velocity and cutting load

Draw the graph of the relation between the cutting load and the drum velocity according to the experiment, and the result is shown in Figure 5. From the figure, we can see that the cutting resistance and resistance to radial mean and mean peak value decreases with increasing cylinder speed, the same cutting resistance and resistance force and radial mean peak value decreases with increasing cylinder speed, and the theoretical formula according to the simulation results. That is the reason that with the increase of the drum speed, the instantaneous speed of the impact of the coal will be increased, and the energy required for coal and rock fragmentation is certain, so the cutting load will be reduced. Comparing the fourth chapter homogeneous coal rock cutting trend and causes of the load, in this experiment the cutting load is grown with the rotation speed of the roller cutting load is reduced, not only because of inertia movement process increases, increase the impact crushing, also influenced by the reduced coefficient of friction. To improve the friction coefficient with relative velocity decreases when the relevant sliding velocity of coal and steel increased from 0.1 m/s to 3.1 m/s, the friction coefficient decreased from 0.4 to 0.15, it will affect the cutting load to a certain extent, namely the higher the speed of the load is small. Cut coal seam conditions in the interface section, considering the increase of cutting power and improve roller speed achieved in the coal seam rock stripping and fragmentation of the most direct and effective means in satisfying the equipment size, by optimizing the cutting motor design, can significantly improve the thin seam (especially is the coal rock interface of coal mining efficiency). In different pick test conditions, the amplitude of the cutting force can be seen, with increasing cutting frequency, the cutting force decreases, but in high speed under the experimental conditions, the cutting force is rising, and the simulation results coincide.

### 3.4 Cutting thickness Experimental study




(a) Cutting resistance (b) Radial resistance

**Fig. 6.** Relationship between cutting thickness and cutting load

According to the data in Figure 6, it can be concluded that the average variation of cutting resistance, radial resistance, and maximum average value will increase with the growth of the roller's forward velocity. On the grounds of the vibration amplitude of cutting force variation, the cutting force will show approximately exponential change with the increase of cutting thickness, and the greater the cutting thickness, the more obvious the fluctuation of cutting force. According to the above test results, the cutting load will increase with the advanced velocity of the drum, which is in keeping with the simulation results. Because the speed of the drum in this section is unchanged, the traction speed increases will lead to the increase of the thickness of the cutting, cutting thickness, of cutting load will be significantly increased; the cutting load peak average growth was significantly greater than the mean cutting load increase. The reason for this phenomenon is that the advancing speed of the roller grows with the growth of the cutting thickness. So, the corresponding cutting block caving degree is bigger, so the cutting process of cutting pick formation from the dense nuclear force required to block coal caving is also bigger, so the peak load increase was obvious.

# 4 Conclusions

After experimental and theoretical analysis, on which the cutting loads of a single pick are taken as the judgment standard based on, we have researched the influence of the parameters of cutting material, the parameters of the cutter structure, the parameters of the cutter installation, and the dynamic parameters on the cutting efficiency of the cuter under the condition of coal-rock connection. In this experiment, the cutting load rises with the growth of the compressive strength of coal strata, and the variation and theoretical study on the cutting performance of material parameters on the cutting load is consistent; with the increase of cutting energy consumption with compressive strength of coal strata increases, indicating the compressive strength on the cutting ratio the energy consumption of a significant impact. It’s concluded that the cutting load grows with cutting thickness and tooth tip angle in the experimental range. The cutting load will decrease according to the drum speed growth. The cutting load will first grow and then reduce because of the growth of the impact angle, and the minimum load will be obtained at the impact angle of about 48 degrees.

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