The International Journal of Engineering and Science (IJES)
|| Volume || 14 || Issue 9 || September || Pages || PP 44-48 || 2025 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Experimental Evaluation on Underground Separation of Coal and Gangue Using Toothed Roll Crusher

Kwang Myong Nam, Kyong Il Ri*, Chang Il Kim
Faculty of Mining Engineering, Kim Chaek University of Technology, Pyongyang, Democratic People's Republic of Korea
Corresponding Author: Kyong Il Ri, Email address: rgi71425@star-co.net.kp

----------ABSTRACT----------
A novel selective crushing device for underground separation of coal and gangue was introduced. Coal and gangue mined in the coal mine were used in experiments for selective crushing and feasibility of using a new structure of toothed roll crusher to achieve selective crushing was experimentally studied. The experiments were carried out with single crushing method of coal and gangue and selective crushing method of mixtures of coal and gangue. The results of crushing experiments on coal and gangue using this crusher showed that coal with a particle size of 100-150 mm was all crushed to less than 50 mm and the gangue was almost uncrushed. This confirms that the toothed roll crusher considered can be used for underground separation of coal and gangue. The results of this study could help to reduce the costs of coal preparation and environmental pollution by effectively implementing underground separation of coal and gangue in coal mines.
KEYWORDS;- *Selective crushing, Underground separation, Toothed roll, Environmental pollution, Crushing experiment*

Date of Submission: 15-09-2025 Date of acceptance: 30-09-2025

I. INTRODUCTION

As the depth of mining increases and the proportion of mechanization increases in coal mines, the raw coal is mixed with a lot of gangue. The lots of gangue will reduce the separation efficiency of the coal-cleaning equipment and increase the cost of coal preparation. Also, increasing the amount of gangue will cause environmental pollution [1, 2].

Underground separation of coal and gangue from coal mines can be of great help in saving the costs of coal preparation, providing backfill materials and solving the problem of environmental pollution [3, 4]. Also, underground separation from coal mines can be effective in saving the cost of transport and reducing the amount of wastes [5]. So far, several underground separation technologies, such as direct impact screening of coal and gangue [1], coal and gangue separation systems based on X-ray detection techniques [6], rotational shock separation methods [7], and separation based on the machine vision system [8], have been developed and operated.

In general, rocks have different physical and mechanical properties, including strength and coefficient of elasticity. Selective crushing method is based on the difference in hardness of coal and gangue [9-11]. Selective crushing is one of the physical separation methods that separate the minerals of different strength. In the selective crushing, the appropriate force applied to the mixture makes that high strength rocks or minerals are not crushed or less crushed and low strength rocks or minerals are crushed or crushed primarily. Then the sieves are used to separate the crushed mixture [12, 13]. The toothed roll crusher has a wide prospect of being used in underground crushing due to its low installation height and suitability for crushing of wet materials compared to other types of crushers [14, 15].

In present study, a novel structure of toothed roll crusher for separating of coal and gangue was designed and tested. In this study, the feasibility of using a novel structure of a toothed roll crusher to achieve selective crushing is experimentally investigated and the applicability of underground separation of gangue is confirmed.

II. STRUCTURE AND WORKING PRINCIPLE OF A TOOTHED ROLL CRUSHER

The toothed roll crusher in this study consists of a single toothed roll, several hanging rings supported by a suspension beam and a support shaft, a machine frame and driving devices (Fig. 1).

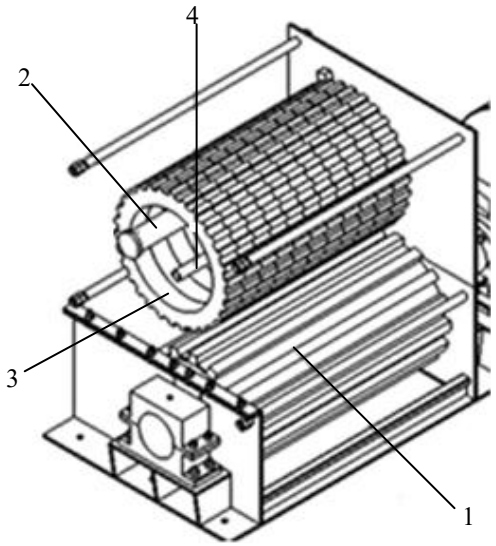

Figure 1. Structure of a toothed roll crusher,
1- Toothed roll, 2- Suspension beam, 3-Hanging ring, 4- Supporting rod.

The technical characteristics of the crusher are given in Table 1.

As shown in Fig. 1 and Table 1, this crusher has a simple structure and the height of about 1 m and the feed size of 150 mm. It is advantageous for underground selective crushing.

Table 1. The technical characteristics of the crusher.

Parameters	Unit	Value
Outside diameter of hanging ring	mm	550
Inside diameter of hanging ring	mm	380
Outside diameter of toothed roll	mm	540
Height of teeth	mm	30
Mass of a hanging ring	kg	70
Feed size	mm	150
Crushing gap	mm	10
Height of crusher	m	1.1
Rotation speed of toothed roll	rpm	60

In this crusher, selective crushing is achieved by the difference in hardness of coal and gangue. The materials in the size range of the feed coal are fed through the stoker. The movement of the feed material is limited by hanging rings. At this time, low-hardness coal is crushed by the toothed roll, and high-hardness gangue is passed through the hanging rings. Thus, the difference in the size distribution of coal and gangue in the crushed materials is existed and can be separated into coal and gangue by using appropriate sieves.

The underground separation process using this crusher is as follows.

First, the raw coal is crushed to less than 150 mm and then selective crushing of coal and gangue in the range of feed size is carried out. The selective crushed materials are screened again through a 50 mm sieve, and the oversize material (gangue) is used as backfill materials and the undersize material (coal) is transported out of the mine.

III. MATERIALS AND METHODS

The samples of coal and gangue were collected from the coal mine.

The characteristics of coal and gangue are given in Table 2.

Table 2. Physical and mechanical characteristics of coal and gangue.

	Hardness, MPa	Density, kg/m^3	Coefficient of friction
Coal	2~15	1 500~1 800	0.38
Gangue	30~60	2 300~2 500	0.53

First, single crushing experiments of coal and gangue were carried out.

The experimental samples were prepared with 30 kg of lumped coal and gangue 100-150 mm in size, respectively. In addition, coal and gangue were divided three groups according to particle sizes, respectively and each group is approximately 10kg (Fig. 2). The coal and gangue samples were fed into the crusher one at a time, and the crushed materials were merged into groups.

a) b)

Figure 2. Samples of coal and gangue(a-coal, b-gangue).

When underground separation of coal and gangue is carried out, selective crushing device is fed with mixture of coal and gangue. Therefore, selective crushing experiments of mixture of coal and gangue were carried out. For selective crushing experiment, three samples were prepared. Each sample was mixtures of coal and gangue in a ratio of 1:1 by weight and its weight is approximately 100kg. Here, the particle size of coal and gangue is 100~150mm. Crushed materials were merged into groups.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The results of single crushing experiments of coal and gangue is as follows.

The crushed materials of coal are shown in Fig. 3.

<10mm 10~25mm 25~50mm

Figure 3. Crushed coal.

The size distribution of the crushed coal was analyzed. The cumulative yields of the crushed coal of each group are shown in Fig. 4.

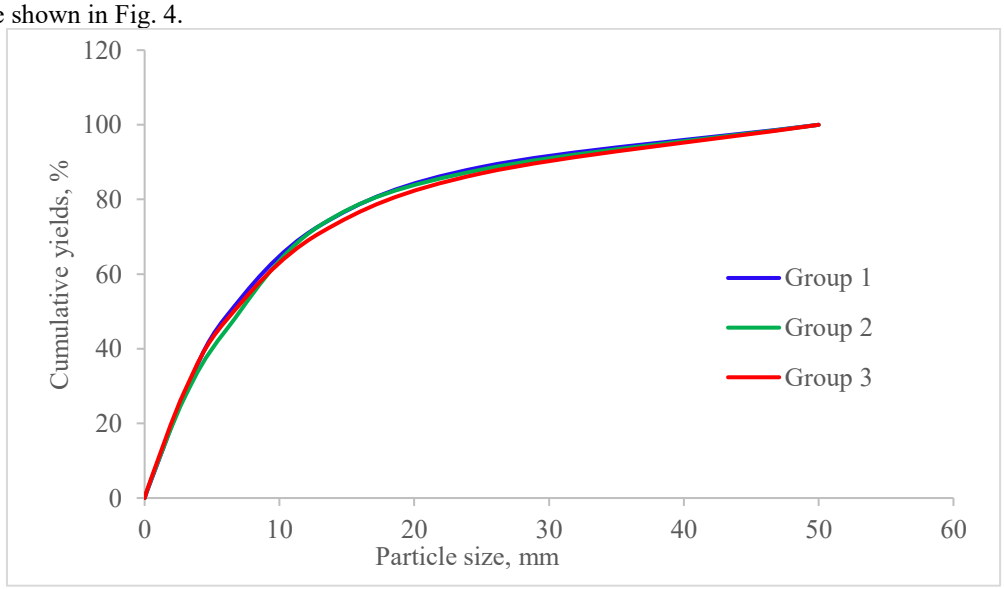

Figure 4. Yield curve with particle size of crushed coal.

As shown in Fig. 4, the maximum diameter of the crushed coal is estimated to be less than 50 mm and it does not depend on the feed size and hardness. The maximum diameter was expected when the height of teeth and crushing gap of the toothed roll was set to 30 mm and the discharge interval to 10 mm. Here, the yield of -30 mm is more than 90%, so reduction ratio for coal of the crusher is close to 5.

The cumulative yields of the crushed gangue are shown in Fig. 5.

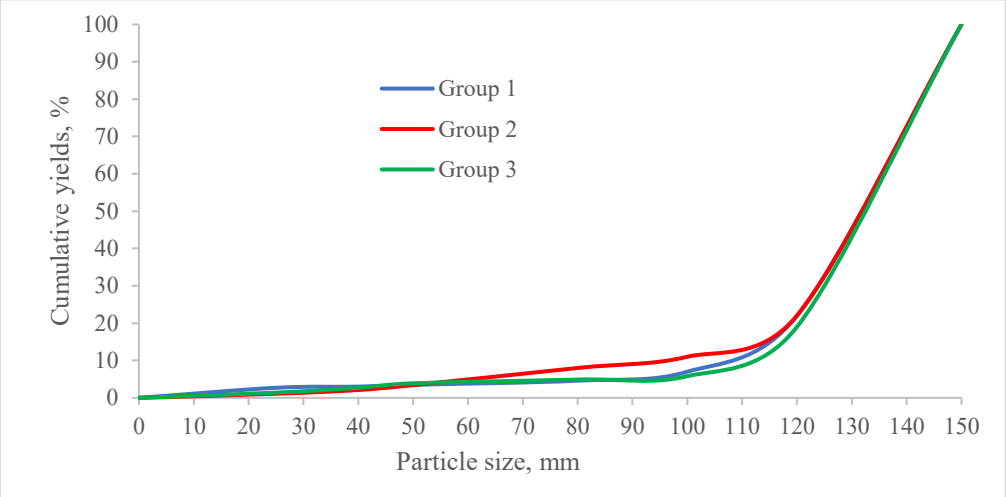

Figure 5. Yield curve with particle size of crushed gangue.

The yield of −50 mm was less than 5%, with most of the gangue samples passing through the crusher without crushing (Fig. 5). Reduction ratio of the gangue is about 1.

The results of selective crushing experiments for the mixtures of coal and gangue are shown in Table 3.

Table 3. The results of selective crushing experiments.

	Mass, kg								Yield, %	
	Coal				Gangue				Coal	Gangue
Size range	1	2	3	average	1	2	3	average		
-150+50mm	3.7	3.1	4.35	3.71	47.35	48.25	48	47.87	7.42	95.73
-50+25mm	12.4	10.6	9.18	10.72	1.5	1.05	1.15	1.23	21.43	2.47
-25+0mm	33.9	36.3	36.48	35.58	1.15	0.7	0.85	0.9	71.15	1.8
Total	50	50	50	50	50	50	50	50	100	100

Coal was mostly crushed to less than 50mm irrespective of particle size and hardness and its yield was more than 90%. More than 70% of coal was crushed to less than 25mm (Table 3). Also, most of the gangue passed through the crusher without crushing, the gangue crushed to less than 50mm was only 3~5%. This result is slightly different from the results of single crushing experiments, the crushing rate of coal is especially lower than that of single crushing experiments. This is because some uncrushed coals pass together when the gangue passes through the crusher without crushing. However, this amount of coal is very small, so the effect on separating efficiency can be negligible.

All the experimental results show that coal can be crushed to less than 50 mm regardless of its hardness and the gangue is almost uncrushed. This shows that selective crushing method by the proposed toothed roll crusher can effectively separate coal and gangue.

V. CONCLUSIONS

This study presents an experimental investigation of the feasibility of applying a novel structure of the toothed roll crusher to underground selective crushing separation. The results of the crushing experiments on coal and gangue showed that the crushing ratio for lump coal is about 5 and the crushing ratio for gangue is about 1, which can effectively achieve selective crushing of coal and gangue. The results of this study confirm that the efficiency of underground separation in coal mines using toothed roll crushers with simple structure and high selective crushing performance can reduce environmental pollution and the costs of transportation and coal preparation.

In this study, the effect of the main parameters of the crusher on the selective crushing efficiency was not considered.

In the future, we will integrate the high-efficiency selective crushing device that can effectively separate coal and gangue by analyzing the effects of structural and operational parameters of the crusher on selective crushing efficiency.

ACKNOWLEDGMENTS

I would like to take the opportunity to express my hearted gratitude to all those who make a contribution to the completion of my article.

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