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Research Article

Screening the Main Factors Affecting the Wear of the Scraper Conveyor Chute Using the Plackett–Burman Method

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The wear of scraper conveyor chute causes both significant economic and environmental losses by shortening the service life. The life of the chute under coal abrasive wear situations is primarily decided by operating conditions and the materials properties. The comprehensive analysis of the influence factors had not been studied before. In this paper, the Plackett-Burman design (PBD) method was used to screen the main influence factors and a regression equation was developed to predict the wear loss. The steel was tested on a modified pin-on-disk apparatus in which coal abrasive was filled in the disk. The influence factors included water content, gangue content, coal particle size, Hardgrove Grindability-Index (HGI) of the coal, normal load, and scraper chain speed. The results of the investigation suggested that the significance of water content, normal load, and gangue content on wear loss was relatively higher than the HGI of coal, scraper chain speed, and coal particle size. The wear loss increased with the increase of water content, gangue content, normal load, and coal particle size while it decreased as increase in HGI of the coal and scraper chain speed. Based on the significance of the parameters, the regression equations were derived and verified further with a number of test cases. Optical microscope studies revealed the main wear mechanism of the chute was mainly micro-cutting and corrosive wear and accompanied by fatigue fracture.

1. Introduction

Fully mechanized mining technology is a mechanized production technology that integrates coal mining, supporting, transportation, and overall propulsion [1–3]. Scraper conveyor is the main transport equipment, as shown in Figure 1. In the hundreds of meters underground, ensuring no damage of the scraper conveyor chute in the production process of a working face is of considerable safe and economic importance. The scraper conveyor chute tribology system consists of three-body wear (scraper-coal abrasive -middle plate) and two-body wear (scraper-middle plate), as shown in Figure 2(a). The failure of the scraper conveyor is mostly caused by an excessive wear of the chute, as shown in Figure 2(b). Wear by coal abrasion is the critical problems in the chute. The life of the chute under coal abrasive wear situations is primarily decided by operating conditions and the materials properties. For maximising the service life of the chute and ensuring no chute damage during a face working, equipping proper chute steels according to different mining conditions is, however, still needed.

Martensitic steels are being used as cost effective materials for wear and abrasion resistant application chiefly because of their greater hardness and relatively higher toughness as compared to high chromium irons, which exhibit excellent abrasion resistance [4]. To increase the service life of the chute and to meet higher demand for the scraper conveyor, high strength martensitic wear resistant steels are widely used for the manufacturing of conveyor chute. Despite numerous studies on the behavior of wear resistant steels in the varying impact conditions [5–7], the performance of these steels in the abrasive conditions especially in the coal abrasive condition has not been widely studied. Deng [8] and Rendon [9] had investigated the abrasive wear behavior of martensitic

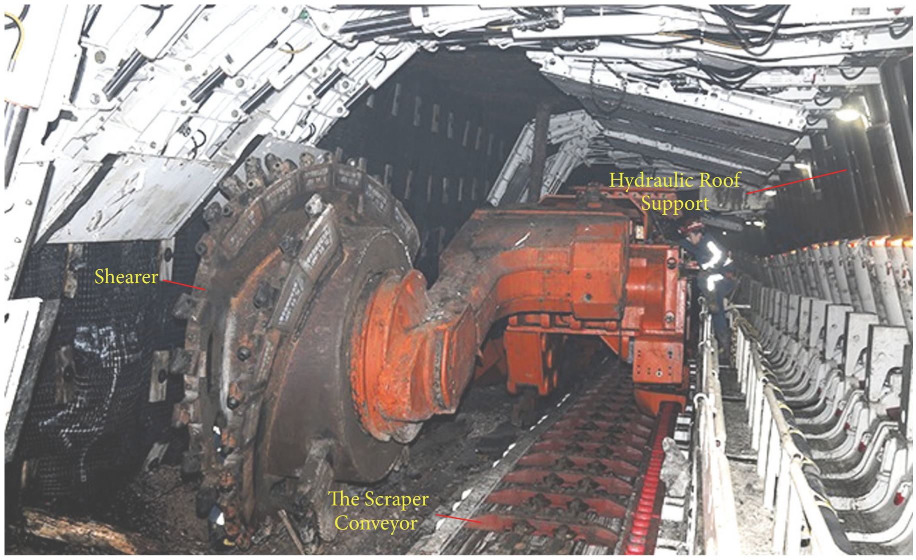
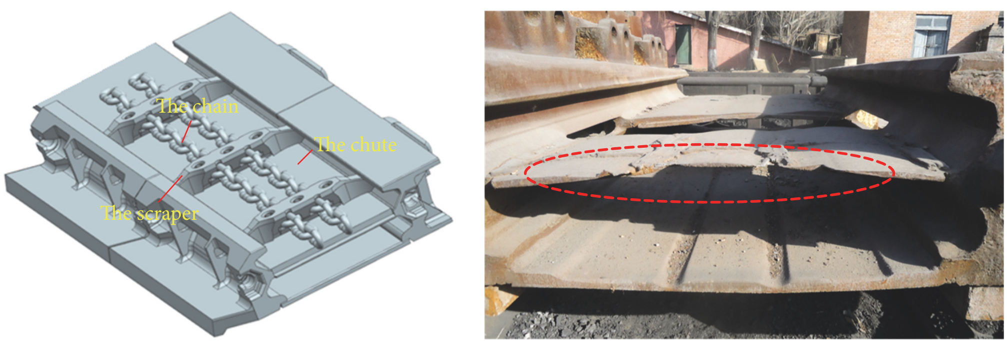


FIGURE 1: Layout drawing of scraper conveyor.



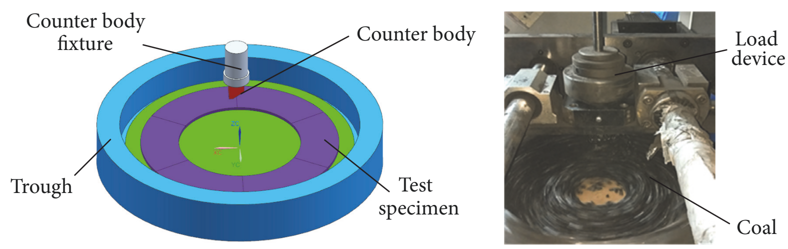
(a) (b)

FIGURE 2: The scraper conveyor chute.

steel through the three-body impact abrasive wear and two-body abrasion, respectively and suggested that the optimal hardness and toughness match was the main reason of higher wear resistance. Chen [10] reported that martensite steels quenched and tempered at lower temperatures show micro-cutting mechanism, while those tempered at higher temperatures showed micro-ploughing mechanism.

Many studies have shown that abrasive wear was related to the contact pressure, sliding speed, and mixed abrasive composition [11]. The wear resistance of the chute used under coal abrasion conditions is decided by the severity of the operational parameters, and properties of the coal abrasive. Shao [12] studied the abrasive wear characteristics of coal. It was considered that the hard-abrasive wear would occur when the hardness ratio of coal to metallic material was greater than 0.64 and the wear rate would increase with an increase in the quartzite content in coal. Yaral [13] investigated the influence of coal types and high quartz content in coal on tool wear. The results showed that an increase in the rock content, average grain size, quartz, and other material contents in coal would have a direct impact on tool wear. Currently, the influence of particle size, slip velocity, and normal load on abrasive wear is considered [11, 14, 15]. However, abrasive factors, such as gangue content, water content, and hardness difference of coal, are seldom considered while studying the wear of scraper conveyor. Unlike an intrinsic property of the material, wear may be presented as a system response related to the tribo-system. With numerous factors and their interactions affecting wear behavior of the chute, it becomes complex to analyze the effect of an individual factor on a particular abrasive wear situation. Design of experiment (DoE) methods allows measuring the significance of the design variables not only when they are acting alone, but also when combined effects are present [16, 17]. DoE based on Plackett–Burman design (PBD) method [18, 19] works at two levels and can be constructed on the basis of fractional replication of a full factorial design. It is a powerful and useful tool in searching for the key factors rapidly from a multivariable system and it can provide some important information about each factor by relatively few experiments. DoE technique has been successfully used by researchers to study the tribological behavior of manganese-steel [20].

The wear behavior of martensitic steels has been investigated in the past under two- or three-body dry abrasive wear



(a) (b)

Figure 3: Schematic diagram of abrasive wear test apparatus.

Table 1: Chemical composition of the test steel (wt%).

Elements	C	Mn	Si	Cr	Mo	S	P
Martensitic steel	0.25	1.22	0.39	0.9	0.6	⩽0.010	⩽0.020

Table 2: Mechanical properties of the test steel.

Mechanical properties	Yield strength (MPa)	Tensile strength (MPa)	Elongation rate (%)	−20°C impact toughness (J)	Hardness (HB)
Martensitic steel	1570	1701	13.23	24	490

situations. Little data is available on coal abrasion response of martensitic steel under the scraper conveyor working condition. To simulate the abrasion of the chute, a modified pin-on-disc apparatus was utilized in the present work. The aim of this paper is to investigate the main factors affecting the wear of the scraper conveyor chute and developing a predictive model. A plan of PBD experiment was used to ascertain all the combinations of six influence factors. The significance of each control factor on the wear response was studied through the Pareto chart and the response table. Based on the main effects plots, the effect of each factor was also noted. In light of the significance of the parameters, regression equation was developed. Finally, optical microscope studies revealed the morphology of the worn surfaces which was attributed to mild to severe coal abrasion test conditions.

2. Material and Methods

2.1. Abrasive Wear Test. To simulate the abrasion of the chute, the experiment was conducted on a modified pin-on-disk abrasive wear tester, as shown in Figure 3. The counter body was made of scraper material, the test sample was made of chute material, and the trough filled with coal was rotated under the electromotor driving. The difference between this test and previous pin-on-disk test was the following: (i) the counter body was designed as a slant structure; thus to encourage the coal particles stuck in the space between the two metals, this can form the similar three-body wear as the coal transportation process; (ii) the present test studied the samples on the disk part, which was different from others investigating the pin part; (iii) the relative sliding between the counter body and the test material was similar to the coal transportation between the scarper and thechute.

The scraper chain speed could be simulated by adjusting the rotational speed of trough with a line speed less than 1 m/s. The test simulated transportation load using weights in a range between 10 and 35 N (including the self-weight of the counter body fixture and the counter body). The wear resistance of the material was evaluated with the mass loss. The specimens were cleaned with alcohol and then weighed using an electronic precision balance (FA3204B, Shanghai, China). After the test, specimens were cleaned with dry compressed air followed by cleaning with alcohol and then weighed. The loss in mass (g) was calculated as the difference of initial and final weight of the specimen.

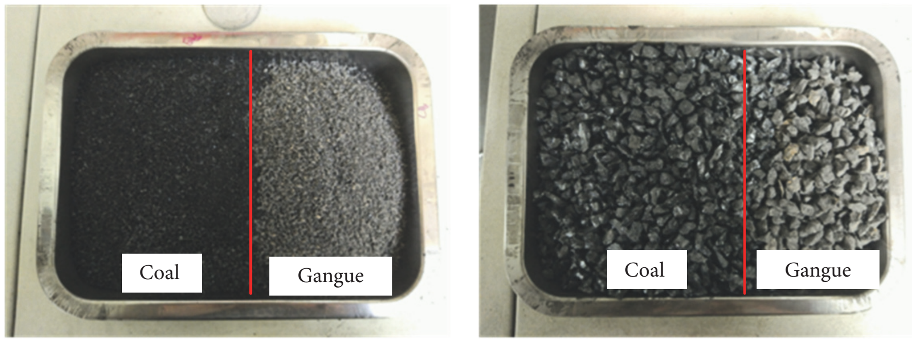
2.2. Test Materials. The chemical composition and mechanical properties of a martensitic wear resistant steel chosen for study are shown in Tables 1 and 2, respectively. The specimens were cut into an angle of 60 degrees fan-shaped piece with an inner and outer diameter of 80 and 130 mm, as shown in Figure 3(a). Test samples were polished with sand paper of 600 meshes. The counter body material selected the commonly used in scraper 40CrMo with the dimension of 20×20×30mm, making a rectangular sample into a trapezoidal sample (Figure 3(a)).

2.3. Experimental Design. Plackett–Burman design (PBD) is a kind of balanced incomplete blocks method. It has been proven to play an important role in the first stage of complex parameter experimental research [21–23]. In the Plackett-Burman design, at most *n-1* variables can be studied by *n* experiments. Each variable has two levels, high and low. The high and low levels appear *n/2* times, respectively.

The PBD method is indicated by a linear model. It was calculated using the following equation:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i, \tag{1}$$

where Y is the tribo-response, β_0 is a constant, β_i are the regression coefficients, and X_i represent the influence factors.



(a) The coal particle size of 0.5–2 mm (b) The coal particle size of 6–8 mm

Figure 4: Coal bulk material.

Table 3: HGI of the coals.

Source place of coals (all in China)	Ningxia	Shanxi	Shaanxi
HGI	51	75	58

Table 4: Mohs hardness of the gangue.

Source place of gangue (all in China)	Ningxia	Inner Mongolia	Shanxi
Mohs hardness	6	4	4

The selection of influence factors and their levels is made based on the survey of the literature, factory investigation, and the lab experiment condition. The wear resistance of the middle plate is decided by the operational parameters and the properties of the bulk coal. In this paper, the following six factors were considered: the properties of the bulk coal like HGI, water content, gangue content, particle size, the operational parameters like normal load, and scraper chain speed.

(1) HGI of Coal. The grindability of coal is a comprehensive physical property related to the hardness, strength, toughness, and brittleness of coal [24]. It could be expressed by HGI, which can be measured using Hardgrove method. Coals from three different provinces in China were prepared for the test, including Ningxia, Shanxi, and Shaanxi coal. The HGI of the coals were tested using a testing apparatus (HA60X50, Changsha, China), and the results are shown in Table 3. Ningxia and Shanxi coals were chosen as testing coal for the large data gap.

(2) Water Content in the Coal. It is well known that water is one of the most effective strength reducing liquids for coal. Perera and Connell reported that the moisture content would cause coal swelling/shrinkage and mechanical properties change [25]. Pan has indicated that Young's modulus of coal is reduced by about 16% due to water [26]. However, the effect of the water content in the coal abrasive wear has not been investigated much. In order to understand it, further investigations were carried out using 0% and 15% water content coal. The 0% coal was obtained by drying in a vacuum drier at 150°C for 3 h. To obtain 15% coal, water was added to the bulk material, mixed until a smooth mixture was formed, and finally kept sealed for 3 days, allowing water to penetrate more effectively.

(3) Gangue Content in the Coal. According to Li and Yang, there were great differences between coal and gangue in hardness, crushing rate, and resistance to impact crushing [27, 28]. The different gangue content inevitably affected the chute wear. Three kinds of gangue were chosen for the test and measured with the Mohs scale, as shown in Table 4. The three gangues were mixed according to 1:1:1 as the experimental gangue. Two sets of gangue content were chosen to study the gangue influence, 0% and 25%.

(4) Particle Size of the Coal. The abrasive size played an important role in the steel wear [20, 29]. Liang had carried out the effect of coal particle size on the chute wear loss. The larger the particle size, the greater the wear loss [15]. However, the particle size was in the level of micron which was not correspondent with the practice. In this paper, through the factory investigation and the lab condition, the particle sizes of 0.5–2 mm and of 6–8 mm were selected to study the effect on the wear. Coal and gangue were screened out through sieves of different sizes, as shown in Figure 4.

(5) Normal Load. Based on the working capacity of scraper conveyor, referring to relevant literature [11, 14, 15] and lab equipment contact area, the normal loads were set to 10N and 35N.

(6) Scraper Chain Speed. Based on the operation conditions of scraper conveyor and abrasive wear test apparatus, the scraper chain speeds were 0.4m/s and 0.9m/s in this paper.

The PBD method was used to analyze the influence of six factors on the wear loss. The high and low levels of the parameters are coded as +1 and -1, as shown in Table 5. In this study, 12 experiments were conducted. Three repetitions were performed for each condition. Experiment design matrix was created and statistical analyses were performed using Design expert 8.0.

Table 5: Parameters of PBD test.

Symbol	Parameters	Low level (−1)	High level (+1)
A	Water content in the coal (%)	0	15
B	Gangue content in the coal (%)	0	25
C	HGI of coal	51	75
D	Coal particle size (mm)	1(0.5~2)	7(6~8)
E	Normal load (N)	10	35
F	Scraper chain speed (m/s)	0.4	0.9

Table 6: Design and results of Plackett–Burman test.

Parameters	Run No.											
	1	2	3	4	5	6	7	8	9	10	11	12
A	-1(0)	-1	-1	-1	1(15)	1	-1	1	1	1	-1	1
B	1(25)	-1(0)	1	1	1	-1	-1	1	1	-1	-1	-1
C	1(75)	-1(51)	1	-1	1	-1	-1	-1	-1	1	1	1
D	1(7)	-1(1)	-1	1	-1	-1	1	1	-1	1	-1	1
E	-1(10)	-1	1(35)	1	-1	1	-1	1	-1	1	1	-1
F	-1(0.4)	-1	1(0.9)	-1	-1	-1	1	1	1	-1	1	1
Wear loss/mg	49	2. 8	53 .8	130. 9	164. 3	223. 1	1 .5	271. 2	108. 4	137	5 .1	59 .2

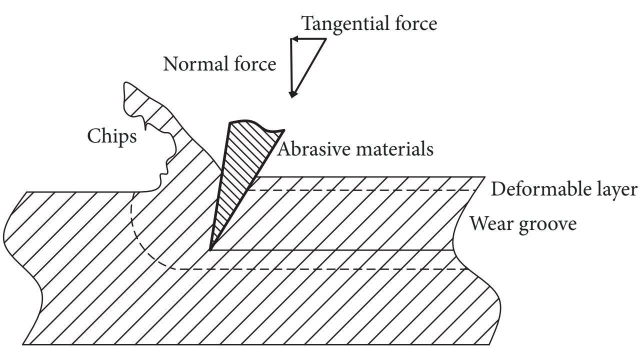


Figure 5: Micro-cutting mechanism model.

2.4. The Abrasive Wear Mechanism. During coal abrasive wear test, the chute bears various complex loads from coal and scraper. The main mechanism of abrasive wear is as follows.

(1) Micro-Cutting Mechanism. The hard particles in coal bulk material rub against the surface of the part, dividing the surface force into normal force and tangential force, as shown in Figure 5. The normal force presses the particles onto the surface of the material, and the tangential force pushes it forward to form a groove. Therefore, the material is either cut to the front end of the groove or plowed toward the two sides of the groove, resulting in deformation, i.e., a fracture. Finally, it flakes off in the form of chips or plow chips from the wear surface. For small cutting width and depth, it is called micro-cutting.

(2) Fatigue Fracture Wear Mechanism. When the soft particles in the coal bulk material are not sharp enough or the metal surface has high strength and plasticity, the slide contact between them will lead to dense dents and lip-shaped ridges on the material surface, as shown in Figure 6. Under the loading of followed coal particles, the convex ridge is flattened. With repeated plastic deformation, cracks will appear in the material surface. While the cracks continue to expand, the metal surface will form flake-like debris and break off.

Characteristics of worn surfaces have been investigated further with an aim to identify the scraper conveyor chute wear mechanisms and to highlight their variations in the main factors. The optical microscope (NMM-800RF/TRF, Ningbo, China) was used to observe the wear patterns of the chute surface morphology.

3. Results and Discussion

3.1. Result Analysis Using ANOVA. The detailed experimental layout for the abrasive wear pertaining to the PBD method is summarized in Table 6. The analysis of variance (ANOVA) results is tabulated in Table 7. In the ANOVA table, the factors and their identification are listed in row 1. The sum of squares is listed in row 2. The degrees of freedom are summarized in row 3. The mean square values for each factor are calculated in row 4 from the sum of squares divided by the degree of freedom. The F-values are calculated in row 5 from the mean squares of factors divided by the mean squares of residual. The P values of the factors are illustrated in row 6 less than 0.05 indicating the model terms were significant. The results show the three influence factors, i.e., water content (A), gangue content (B), and normal load (E), were significant since p value for them came out to be less than 0.05. Based on the ANOVA results, the regression equation was developed which is presented in coded unit as

$$\begin{aligned}\text{Wear loss (mg)} = {} & 100.52 + 60.01 \times A + 29.07 \times B \\ & - 22.46 \times C + 7.61 \times D + 36.32 \\ & \times E - 17.33 \times F \end{aligned} \tag{2}$$

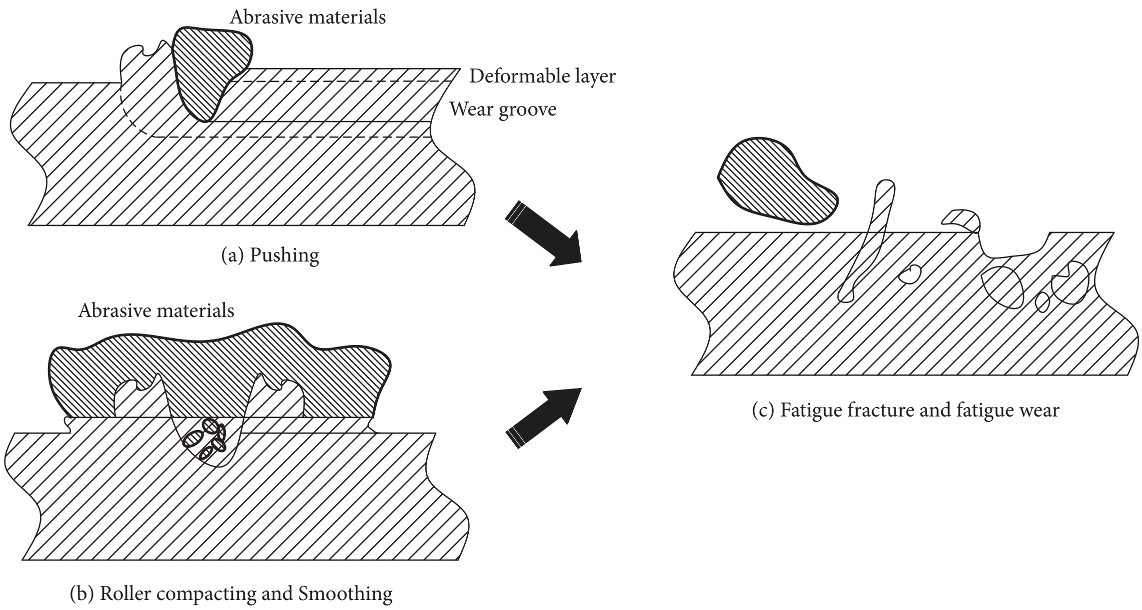


Figure 6: Fracture caused by multiple plastic deformation wear mechanisms.

Table 7: The analysis of variance results.

Source of variation	Degree of freedom	Sum of squares	Mean square	F value	P value (Prob>F)
Model	6	79539.37	13256.56	11.04	0.0093
A	1	43212	43212	35.98	0.0018
B	1	10144.27	10144.27	8.45	0.0335
C	1	6052.52	6052.52	5.04	0.0748
D	1	694.64	694.64	0.58	0.4813
E	1	15834.07	15834.07	13.18	0.015
F	1	3601.87	3601.87	3	0.1439
Residual	5	6005.42	1208.08		
Total	11	85544.78			
R^2=0.9298	R^2 Adj =0.8456	Adeq precision=9.476			

The ANOVA results of the regression model are shown in Table 7. The results indicated that the p value of 0.009 3 is less than 0.05, which shows that the model was significant. It is generally considered that the compound correlation coefficient $R^2 > 0.8$ indicates the regression model and the actual value conform very well [18]. The correction coefficient R^2_{Adj} was 0.8456, indicating that 84.56% of the variability of experimental data could be explained by this regression model. Adeq precision measures the signal to noise ratio. A ratio greater than 4 is desirable. This model ratio of 9.476 indicates an adequate signal.

3.2. Variables Effect on Wear Behavior. Towards a greater understanding of factors which influenced the wear loss, they have been analyzed by means of (i) Pareto chart and the response table and (ii) main effects plots.

3.2.1. Analysis Using Pareto Chart and the Response Table. The Pareto chart has been used to analyze the effects of different variables. The graph in Figure 7 illustrates both the magnitude and the importance of a factor. Any factor that extends past the t-value limit reference line is potentially important [30].

The influence of variables on wear loss has been performed using response table, which are shown in Table 8. In response table, the effect of a factor on response variable is the change in the response when the factor goes from its low level to its high level. If the effect of a factor is bigger than zero, the average response is higher for the higher level of the factor than for the low level; otherwise it is higher for the lower level than for high level [31]. From the analysis of Pareto chart and response table, the ranking of the importance of each parameter was water content, normal load, gangue content, HGI of coal, scraper chain speed, and coal particle size.

3.2.2. Analysis Using Main Effects Plots. The effect of variables or process parameters on wear loss is presented in Figure 8. The main effects plots were plotted when the effects in mean level (7.5% water content, 12.5% gangue content, 63 HGI, 4mm coal particle size, 22.5N normal load, and 0.65m/s

Table 8: Response table for wear loss.

Run No.	Wear loss (mg)	A -1	A 1	B -1	B 1	C -1	C 1	D -1	D 1	E -1	E 1	F -1	F 1
1	49	49			49		49		49	49		49	
2	2.8	2.8		2.8		2.8		2.8		2.8		2.8	
3	53.8	53.8			53.8		53.8	53.8			53.8		53.8
4	130.9	130.9			130.9	130.9			130.9		130.9	130.9	
5	164.3		164.3		164.3		164.3	164.3		164.3		164.3	
6	223.1		223.1	223.1		223.1		223.1			223.1	223.1	
7	1.5	1.5		1.5		1.5			1.5	1.5			1.5
8	271.2		271.2		271.2	271.2			271.2		271.2		271.2
9	108.4		108.4		108.4	108.4		108.4		108.4			108.4
10	137		137	137			137		137		137	137	
11	5.1	5.1		5.1			5.1	5.1			5.1		5.1
12	59.2		59.2	59.2			59.2		59.2	59.2			59.2
Tatal	1206.3	243.1	963.2	428.7	777.6	737.9	468.4	557.5	648.8	385.2	821.1	707.1	499.2
Value	12	6	6	6	6	6	6	6	6	6	6	6	6
Average		40.5	160.5	71.5	129.6	123	78.1	92.9	108.1	64.2	136.9	117.9	83.2
Effect		120		58.1		-44.9		15.2		72.7		-34.7	

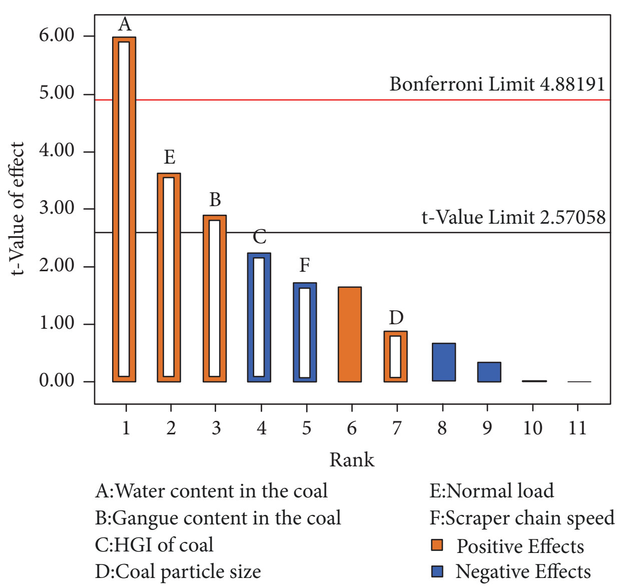


Figure 7: Pareto chart of the standardized effects.

scraper chain speed) through the regression equation (2). It can be observed that wear loss increases as increase in water content, gangue content, coal particle size, and normal load. However, the plots exhibit that wear loss decreases as a result of increasing scraper chain speed and HGI of coal. Similar trend was observed in Pareto chart and the response table.

Due to the addition of water, the cohesive force of the coal particles increased which made the loose rolling particles into fixed sliding particles. In addition, the water containing dissolved acidic materials leads to corrosion of the steel. The wear loss by increasing the water content from 0 to 15% had experienced a threefold increase in the present work. It shows that the wear loss increases due to the fixed sliding particles as well as the acidic water. According to the work of Shi [11], the greater the gangue content, the more serious the material wear. This result was consistent with the one present here. As has been seen in previously published data sets for pin-on-disk abrasive wear tests [20], the trends of wear loss have increased due to the increment of normal load and particle size. As a general rule, higher HGI values mean that the fuel is easier to grind, requiring lower power inputs in the mill [32]. The results present here show that the wear loss decreased as an increase on HGI of coal. In addition, in this study here presented, at a specific wear distance, the enhancement of the speed led to reduction in wear loss.

3.3. Validation of Regression Model. By this reckoning, the regression equations were developed based on the results of ANOVA using adjusted sum of squares for tests. From the ANOVA in Table 7, the control factors were noted based on the P values. In the optimal regression equation the influence parameters observed to be P value bigger than 0.05 in Table 7 were not considered. The regression equations for the prediction of wear loss are stated below:

$$\text{Wear loss (mg)} = -53.94333 + 8.00111 \times A + 2.326 \times B + 2.906 \times E, \quad (3)$$

where A is water content, B is gangue content, and E is normal load.

The regression equation was validated with a number of test cases. Table 9 presents the results of these validity tests. It had been observed that the percentage error for wear loss is less than 20%. It is evident that the regression model can be used to predict the wear loss in coal abrasion test.

3.4. The Wear Mechanism Analysis. The wear surfaces under mild working condition test PBD-2 (0% water content, 0% gangue content, 51 HGI coal, 1mm particle size, 10N normal

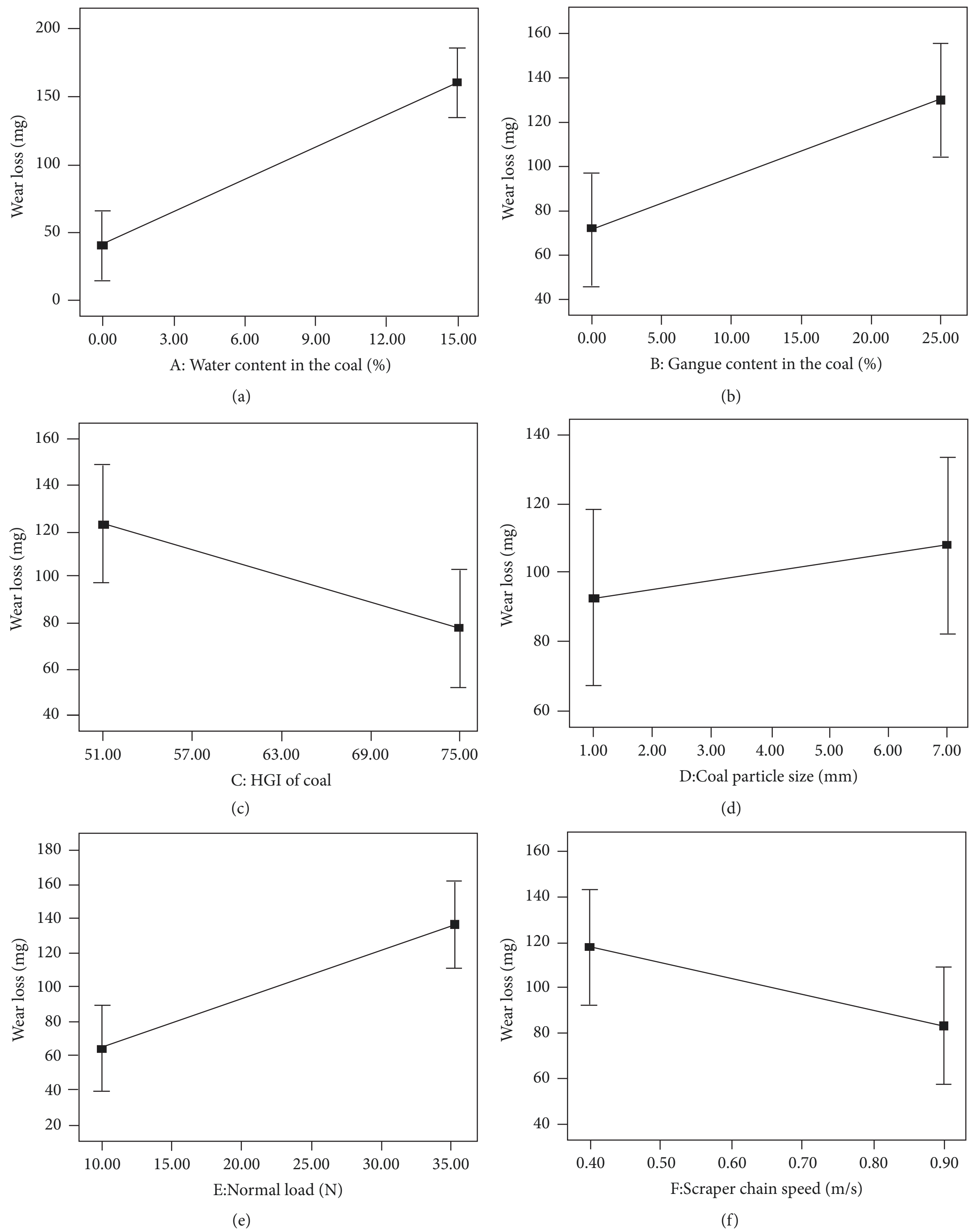
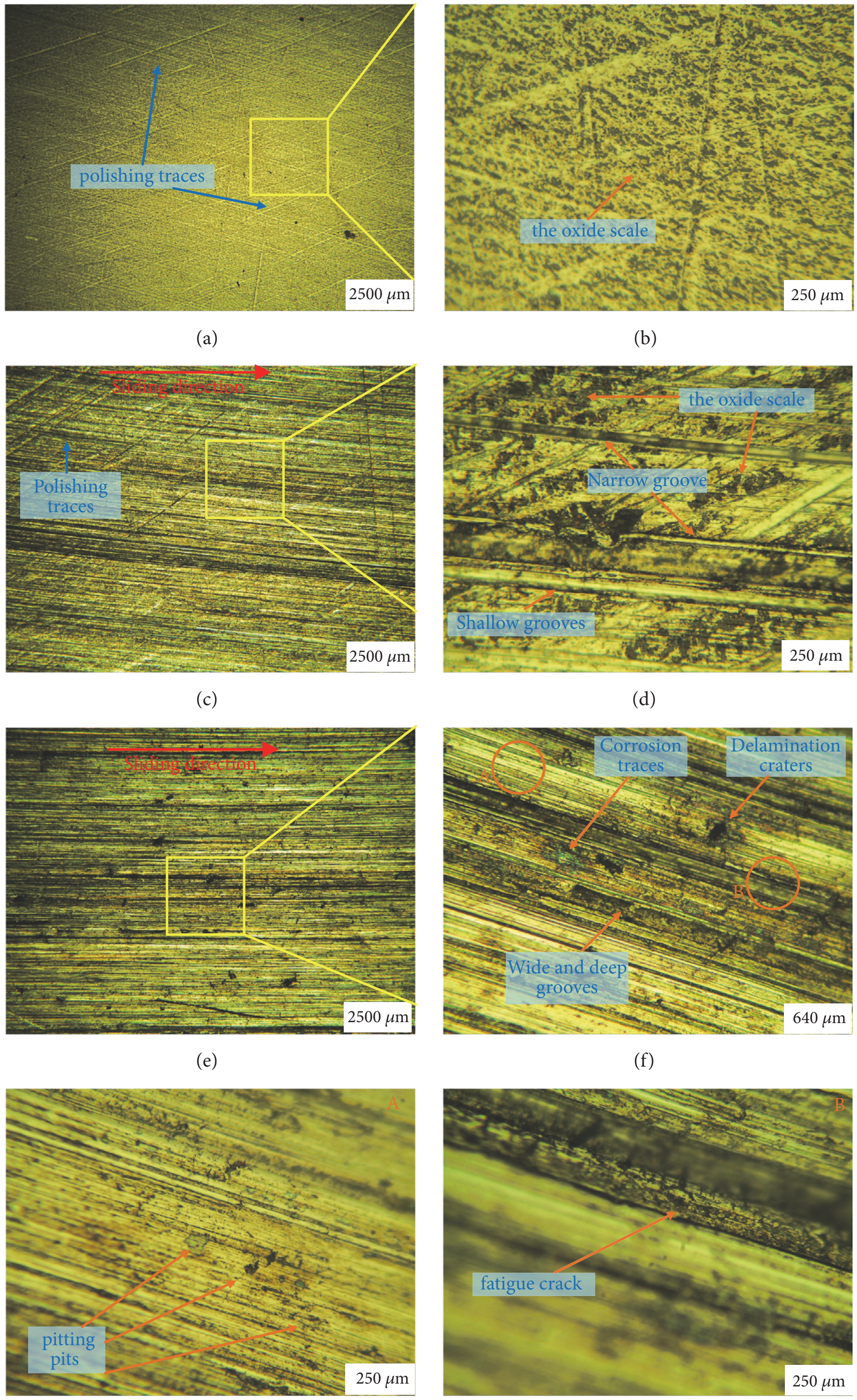


Figure 8: Main effects plots for the martensitic steel.

load, and 0.4m/s scraper speed) and severe working condition test PBD-8 (15% water content, 25% gangue content, 51 HGI coal, 7mm particle size, 35N normal load, and 0.9m/s scraper speed) had been selected for analysis. Furthermore, the wear loss of PBD-8 is 96.8 times (see Table 6) that of PBD-2.

Figures 9(a) and 9(b) show the morphology of the test piece before the wear test. The micrographs show the polishing traces and the oxide scale due to polishing process. Under mild working condition, the worn surface of the steel (Figures 9(c) and 9(d)) is characterized by long, narrow, and shallow grooves. The polishing traces and oxide scale



(a) (b) (c) (d) (e) (f) (g) (h)

FIGURE 9: Wear surface morphology of the martensitic test piece under unworn condition (a)(b), under PBD-2 condition (c) (d), and under PBD-8 (e) (f) (g) (h).

were still on the surface. The grooves were formed when soft coal particle was pressed by the counter body. The main wear mechanism was micro-ploughing under mild working condition.

Under severe working condition, the traces under polishing process have been worn off and replaced by grooves, delamination craters, pitting pits, and corrosion traces (Figures 9(e) and 9(f)). In this case, the gangue content increasing

Table 9: Comformation test results and comparison with regression model.

Run No.	Water content (%)	Gangue content (%)	Normal load (N)	Wear loss (mg)	Predicted wear loss (mg)	Error of wear loss (%)
1	0	15	25	46.8	53.6	14.5
2	5	5	10	33.2	26.75	19.42
3	10	10	20	92.1	107.44	16.65
4	15	15	20	133.4	159.08	19.25

would widen grooves and increase furrow density and depth; meanwhile there were delamination craters caused by the harder gangue particles (Figure 9(f)). In addition, the water in the coal had led to the corrosion traces and pitting pits on the surface (Figures 9(f) and 9(g)). With an increase in the load, the contact surface of the counter body and test piece increased; this produced radial cracks perpendicular to the surface and extended to the interior (Figure 9(h)).

In summary, with the increase of gangue content and the normal load, the wear mechanism was micro-cutting. The increase of water content aggravated the corrosion of the chute surface. According to the comprehensive analysis, the wear mechanism of the scraper conveyor chute was mainly micro-cutting and corrosive wear and accompanied by fatigue fracture.

4. Conclusion

In the present study, we screened the main factors affecting the wear of the scraper conveyor chute and developed a predictive model. The Plackett-Burman design was used to analyze the influence of six factors (water content, gangue content, particle size, HGI, normal load, and scraper chain speed) on the scraper conveyor chute wear loss. The results support the following conclusions:

(1) Through the analysis of ANOVA, the Pareto chart, and the response table, the main factors affecting the wear of scraper conveyor chute were the water content, gangue content, and normal load, whereas other factors had relatively less impact.

(2) The analysis of the main effects plots showed that, with the increase of water content, gangue content, coal particle size, and normal load, there was an increase in the wear loss. However, wear loss decreases as a result of increasing scraper chain speed and HGI of coal. This was obtained on the basis of a certain wear distance.

(3) Based on the main factors, the regression equations were derived and verified further with a number of test cases to adequacy of the model. It had been observed that the percentage error for wear loss is less than 20%. It is evident that the regression model can be used to predict the wear loss in coal abrasion test.

(4) The wear mechanism of the steel under the coal abrasive condition was studied using optical microscope. With the increase of gangue content and the normal load, the wear mechanism was micro-cutting. The increase of water content aggravated the corrosion of the chute surface. The wear mechanism of the scraper conveyor chute was mainly micro-cutting and corrosive wear and accompanied by fatigue fracture.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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