

## AUXILIARY INTELLIGENT OPERATING SYSTEM FOR DRAGLINE STRIPPING EQUIPMENT IN SURFACE MINING

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**Abstract:** In order to improve operation skill of the operators, the design of the auxiliary intelligent operating system of the dragline was studied. Whereby the gyroscopes incorporated in smartphone and data sequence filter algorithm, the automatic collection function of operation cycle, the rotation angle and other parameters of the dragline are attained. In line with the relations among the rotation angle of equipment operation, time-spent and the acceleration, the ratio of the acceleration and deceleration rotation angle in full load rotation and non-loaded return stage are acquired respectively. The function of bucket in rotation was realized. Comprehensive score calculation standard of the technique level of the dragline-based operation was developed, and the function of automatic checking the operation level was effectuated. Field experiment results indicated that the operators' faults are markedly reduced as the auxiliary intelligent operating system is employed. By using the system the operation behavior of low power slow rotation in rain, snow, low atmospheric pressure and other severe weather conditions can be reduced, assuring all-weather efficient and safe operation of dragline.

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**Keywords:** *dragline stripping; intelligent operating system; operational efficiency*

### 1. INTRODUCTION

Dragline stripping is the method primarily used in surface mining in the United States, Australia, Canada, Russia and other major coal-producing countries. The

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dragline is at the core of equipment employed in this method, incorporating mining-transport-dumping functions. Maximum bucket capacity of dragline reaches up to  $168 \text{ m}^3$ , the maximum operating radius reaches 120 m, and the maximum stripping thickness is attained as 60 m. Practice indicated that the production cost adopting this method was merely 1/2–2/3 of other methods, and the production efficiency was 40%–60% higher than that of other methods (Gilewicz, 2000; Ridley, Corke, 2001). The factors affecting operation efficiency and the measures to increase equipment efficiency were ascertained through adopting qualitative analysis, quantitative calculation and other methods regarding engineering practice by Wang Gui-lin(2012), Chen Chun-yang (2014), Liu Tong (2014) et al. The dragline operation cycle was elucidated whereby the detailed calculation and analysis of Erdem et al. (2005; 2012), the distribution of cycle and idle time of dragline operation was ascertained by Rai et al.(2000), Costello and Kyle (2004) established the excavation attitude model of the dragline with dynamic simulation method, the force of the bucket was anatomized to lay the foundation for optimizing the operation of dragline. Dragan Komljenovic et al. (2010) studied the dragline efficiency evaluation method (OPI) with the hourly excavation amount and energy loss as the main index, and on that basis a new idea was proposed to evaluate the efficiency of the dragline. All of the foregoing research explicitly highlighted that the level of the operation of the dragline was the crux affecting the stripping efficiency. However, arising from complicated operating conditions and difficulties in data collection, this study is confined into the qualitative discussion.

Given the foregoing situation, intelligent assistant operation system in the light of sensor technology of smartphone was studied and designed. The automatic acquisition of main equipment operating parameters, automatically prompts of equipment in rotation, automatic evaluation function of operational level can be effectuated whereby this system, which markedly elevate the skill level of the operator and the equipment efficiency.

## 2. RESEARCH BACKGROUND

Heidaigou surface mine is located in the middle of Zhunge'er coalfield in Inner Mongolia Autonomous Region, China. In 2007, Heidaigou surface mine applied dragline stripping technology for the first time, the dragline was manufactured by the Bucyrus Company, with  $90 \text{ m}^3$  bucket capacity and 100 m maximum operating radius. In excess of 40 m thick rocks above the top of the No 6 coal seam (thickness is about 30 m) were stripped by the dragline after blast casting. Dragline stood on the blasting pile which flatted by shovels and bulldozers. The broken material was dumped to the emptied pit by dragline. The main elements of working face are exhibited in Fig. 1.

The coal production of Heidaigou surface mine reached 34 million t/a after the application of dragline stripping and blast casting technology, which made the mine to be the largest and most efficient modern surface mine in China. The successful application of the dragline stripping technology in Heidaigou surface mine has evidently elevated the production efficiency and markedly reduced the production cost, and it also boosted the development of the surface mining technology in China. However, surveys indicated that the average production capacity of Bucyrus 8750-65 type dragline employment in Heidaigou surface mine was currently less than  $16 \text{ Mm}^3/\text{a}$ , a data not reaching 65% of the designed annual production capacity. The dragline stripping system was equipped with a shovel, 4 trucks to assist dragline stripping operations, the amount of auxiliary work is about  $13 \text{ Mm}^3/\text{a}$ . Operators operated only whereby the accumulated experience and the deficient theoretical guidance regarding equipment operation skill. There were even no effective assessment standards for dragline operation.



Fig. 1. In-place view of typical dragline operating condition  
(1 – high bench; 2 – keycut; 3 – coal roof; 4 – coal ditch; 5 – extended bench; 6 – spoil pile)

The mining operation time of dragline was approximately 4000 h per year. If the average cycle time is acquired as 70 s, the number of operating cycles is 205714 times. If the average cycle time is shortened as 1s, the operation cycle of the equipment shall increase 57.14 h (about 2.4 days) throughout the year, and annual production capacity of dragline shall rise approximately 156,000 tons (about  $230,000 \text{ m}^3$ ). The increase of dragline production capacity shall simplify the assistance conducted by the shovel-truck technology. The current overall production cost of dragline was about 13.07 yuan/ $\text{m}^3$ , and shovel-truck production cost of the stripping system was about 18.56 yuan/ $\text{m}^3$ . For this reason, about 1.26 million yuan can be saved per year in stripping if average job cycle time can be shortened as 1 s. Therefore, it is of great significance to elevate the skill level of the operator (Sun Jiandong 2016).

### 3. AUTOMATIC ACQUISITION METHOD OF EQUIPMENT OPERATING PARAMETERS

The long-term and continuous field collection and measurement are required by the time statistics in the rotation process of equipment operation. At present, manual records were extensively adopted in the domestic and international research, and the collected data had characteristics of discontinuous, few of samples, more mistakes, etc. Rare studies adopted the database of programmable logic controller (PLC), structured query language (SQL) and other methods required to be supported by software and hardware of dragline control system (Komljenovic et al., 2010; Demirel, ., 2011). Yet arising from the long period of research and development of software and hardware, and a high cost, these methods have not yet been extensively employed. This paper proposed a new method of using gyroscopes incorporated in a smartphone to achieve monitoring and recording the operation condition of equipment (Pan Quan, 2007; Chen Chun-Yang, 2014), which could effectively resolve many problems encountered in data collection. The "Huawei Glory 6" smartphone which adopted LSM330-type gyroscopes was adopted in the research. In data acquisition, smartphone was incorporated in driving cab of dragline horizontally. Through running the data acquisition software developed by Android system, the angular rate data should be automatically recorded by the software and stored in the memory card. Meanwhile, the camera was incorporated in the driving cab. The real-time operating situation was recorded for comparison with the sensor data.

As certain error existing in the gyroscopes incorporated in smartphone itself, the actual value of the system was set in a certain moment as  $X_g$  and the measured value as  $X$ . Accordingly the absolute error  $e$  of the sensor measurement is defined as

$$e = |X_g - X|. \quad (1)$$

Through running the angular rate acquisition software under the static condition ( $X_g = 0$ ), the absolute error of the sensor measurement data can be attained. The average absolute error of the sensor in  $n$  time's measurement is defined as

$$\bar{e} = \frac{1}{n} \sum_{i=1}^n e_i. \quad (2)$$

From formulas (1) and (2), it can be acquired that the average error of gyroscopes measurement value of Huawei Glory 6 was  $7.497 \times 10^{-3}$  rad/s.

During the operation of dragline, the machine was being constantly vibrated. Accordingly the data monitored by the sensor is encompassed by the real signals  $g_i$  and

the noises  $\varepsilon_i$ , and it conforms to the following formula:

$$f_i = g_i + \varepsilon_i, i = 1, 2, \dots, n. \tag{3}$$

Given that noise shall exert certain influence on the accuracy of the data sequence, it shall be eliminated as much as possible. Wavelet transform has the time-frequency localization and multi-resolution properties. It could effectively reckon with the acquisition of the original filter to extract the real signal. The specific steps are as follows (Sun Jian-Dong et al. 2016; Liu Zhi-Cheng et al. 2007).

- (1) Select the appropriate wavelet and number of decomposition layers, using Mallat algorithm for orthogonal transformation of noise data sequences:

$$c_{j,k} = \sum_m h(m-2k)c_{j-1,m}, k = 0, 1, \dots, n-1, \tag{4}$$

$$d_{j,k} = \sum_m g(m-2k)C_{j-1,m}, k = 0, 1, \dots, n-1, \tag{5}$$

where,  $c_{j,k}$  and  $d_{j,k}$  are scale coefficients and wavelet coefficients, respectively,  $j$  is the number of decomposition layers,  $n$  is the number of sampling points,  $h$  and  $g$  is the paired orthogonal mirror filter banks.

- (2) The threshold of the wavelet coefficients which attained by decomposition was processed.
- (3) The wavelet coefficients acquired from the second step was reconstructed, which attained the optimal estimation of the original signal.

$$c_{j-1,m} = \sum_k c_{j,k}, h(m-2k)c_{j-1,m} + \sum_k d_{j,k}, g(m-2k). \tag{6}$$

In line with the response characteristics and filtering requirements of the rotational angular rate of the dragline, the Meyer wavelet was perceived as the mother wave, and the data was decomposed by 5 layers whereby the C language program, and the optimal estimation of angular rate in the actual operation of dragline was effectuated.

## 4. ANALYSIS OF EQUIPMENT OPERATING PROCESS

### 4.1. ANALYSIS OF THE TIME-SPENT OF OPERATING CYCLES

The dragline operating cycles comprise five stages: excavating, rotating with full load, dumping, non-loaded rotating and bucket adjustment (Fig. 2). Stages of

dumping and bucket adjustment can be completed in the process of the equipment rotation. For this reason, the latter four stages can be summarized as the rotation process.

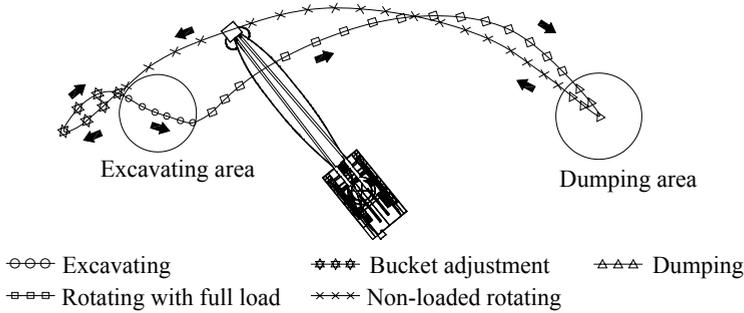


Fig. 2. Dragline operation cycle trajectory division

Table 1. The statistics of cycle of dragline operation under different operation content

Operation content		Average of time-spent/s	Ratio to operation cycle
Coal ditch excavation	Excavating process	12.13	16.50%
	Rotating process	61.5	83.50%
Maincutting	Excavating process	12.04	20.00%
	Rotating process	48.11	80.00%
Keycutting	Excavating process	13.16	21.90%
	Rotating process	46.82	78.10%

Coal ditch excavation: excavate the materials near the bottom line of spoil pile.

In line with the 1200 groups of the dragline operation data samples collected on December 20th –30th, 2014, it can be acquired that time-spent of rotation for operation cycle accounted for 83.5%, 80%, 78.1% respectively in coal ditch, maincut and keycut excavation (Table 1). Therefore, total time consumption of equipment rotation is not only deemed as an important factor affecting the efficiency of equipment operation, but also an important indicator to identify and assess the condition of the operator's operation skill (Sun Jian-dong et al. 2016).

#### 4.2. ANALYSIS OF EQUIPMENT OPERATING STAGES

Given the video record, the device rotation process and the excavating process were split in the filtered data sequence. In Figure 3, the angular rate of “rotating with full load” stage was indicated to be positive, and the angular rate of “non-loaded rotating” stage was denoted to be negative.

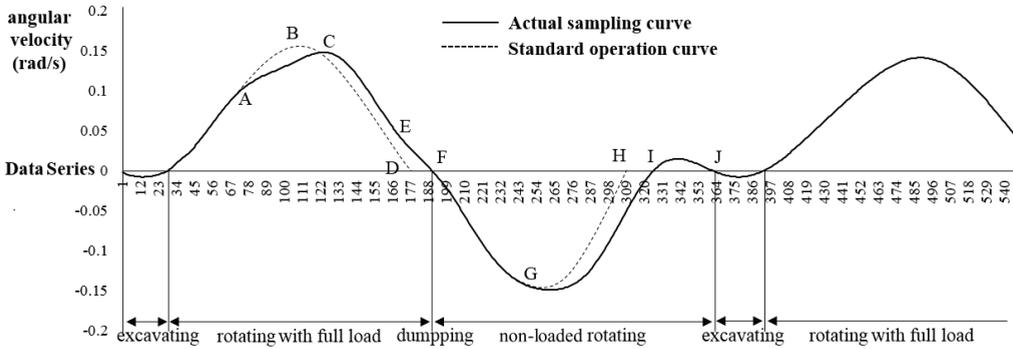


Fig. 3. Analysis of data sequence of angular rate

As the bucket slid in the normal direction of the excavation direction, to avoid drag rope strain, dragline would generally be rotated in a small amplitude. In the process of “full-load rotating”, the equipment first maintained similar uniformly accelerated rotation, and thereupon carried on similar uniformly decelerated rotation. When the dragline rotated approaching to the *F* point, the discharging operation was carried out and completed during the rotation process, and thereupon dragline returns with no load in the reverse direction.

Operating behavior of equipment acceleration and deceleration played a decisive impact on the efficiency of the rotation process. In line with angular rate changes in the equipment operation, the operation behavior can be subdivided into the following categories:

(1) The early deceleration

When the equipment reduced speed in advance, the deceleration must be reduced to ensure the bucket fell in next mining position at the termination of rotation, which increased time-spent for cycle. As exhibited in Fig. 3, in line with the characteristics of the equipment operation, the maximum speed of dragline in “full load rotating stage” can be reached at point *B* and completed at point *D*. But arising from operational error, equipment reduced the acceleration at point *A*, and reduced the deceleration at point *E* in advance, which led to the time-spent increased about 2 s in the stage.

(2) The lagging deceleration

When the equipment decelerated in lag, the bucket would cross the predetermined mining point, which increased time-spent of adjustment. As exhibited in Fig. 3, in line with the characteristics of the equipment operation, “non-loaded rotating” stage shall be decelerated at point *G*, finished stage operation at point *H*. The operators’ mis-

judgment caused equipment decelerated in lag, which resulted in bucket exceeded the predetermined mining position. He had to readjust the bucket position to finish the cycle at point *J*. time-spent increased about 7 s in the stage.

### (3) The low speed rotation

Low speed rotation was common in actual operation. Because of large linear dimensions of dragline and far distance of driving cab from the bucket, it was difficult to judge the relative position from bucket to bench and spoil pile for operators by naked eye when encountered rain, snow, low atmospheric pressure and other weather conditions. To avoid the occurrence of safety accidents, “slow-power & slow rotation” operation shall be generally adopted by the operator, and a single operation cycle time can be up to 80–100 s. It markedly reduced the operating efficiency, and this situation is particularly evident at night;

### (4) The standard operation

In the standard operation, the ratio of accelerating and decelerating rotation angle was approximately  $3/2$  which shall be kept in “rotating with full load” stage. And the ratio was  $4/5$  approximately in “non-loaded rotating” stage. In this kind of operation, equipment operated efficiently, and the operation ability has been fully exploited.

In line with the above analysis, it can be seen that the crux to elevate the efficiency of dragline operating cycles was to increase the proportion of the standard operating cycles to total cycles. But the level of equipment operation was affected by comprehensive influence, such as operating personnel working experience, attention, external environment, and other aspects.

During the operation, the operator cannot guarantee the high concentration of the spirit of the long time, so it is necessary to design a set of intelligent auxiliary operation system to assist the manual operation.

## 5. DESIGN AND IMPLEMENTATION OF INTELLIGENT AUXILIARY OPERATING FUNCTION

### 5.1. PROMPT FUNCTION OF THE EQUIPMENT IN ROTATION

Prompt function of the equipment in rotation was first to determine equipment’s rotation angle from the excavating area to dumping area. On that basis, the turning point of acceleration and deceleration was acquired automatically in line with the average acceleration and deceleration, and prompting the operator to perform the correspond-

ing operation whereby sounds and vibrations. Specific design and research processes are as follows:

(1) Calculation of rotation angle of equipment operation

The relative position change is negligible in contrast with the previous time, and the rotation angle of each operation is determined by the preceding operation. Therefore, the first operation of the dragline requires a complete cycle, the rotation angle of the operation shall be automatically determined by the auxiliary operating system, and the next operation cycle shall start the prompt function. In line with the data sequence collected by the sensor, the actual rotation angle of the dragline is:

$$\theta = \sum_{i=1}^j \frac{(W_i + W_{i+1})(t_{i+1} - t_i)}{2}, \tag{7}$$

where:  $W_i$  is the angular rate of equipment rotation at time  $t_i$ ,  $t_1$  is the start time of full load rotation,  $t_j$  is the finish time of full load rotation.

(2) Judgment of turning point of equipment acceleration and deceleration

Through analysis of dragline operation cycle process, it could determine that the rotation process was similar to the uniform acceleration movement. The average angular acceleration from time  $t_1$  to  $t_j$  in a certain stage was as follows:

$$a = \frac{1}{n} \sum_{i=1}^j \frac{W_{i+1} - W_i}{t_{i+1} - t_i}. \tag{8}$$

The angular rate data series of the 100 groups of operating cycles of dragline were statistically analyzed, and the average acceleration (Table 2) in full power rotational state of equipment was attained.

Table 2. Average acceleration of dragline rotation

Type	Rotating with full load	Non-loaded rotating
Average acceleration/rad·s <sup>-2</sup>	0.0096	0.0145
Average deceleration/rad·s <sup>-2</sup>	0.0144	0.0117

The maximum speed of acceleration and deceleration process of the dragline was the same in full load rotation or return with no load, and it satisfied the following formula:

$$V_{\max} = a_1 t_1 = a_2 t_2, \tag{9}$$

where:  $a_1$  and  $a_2$  denote the angular accelerations, angular deceleration of dragline in one rotation stage,  $t_1$  and  $t_2$  are acceleration time and deceleration time of dragline in one rotation stage respectively. Therefore, the ratio of the rotation angle of the acceleration and deceleration process is:

$$\frac{W_1}{W_2} = \frac{a_1 t_1^2}{a_2 t_2^2} = \frac{a_2}{a_1}. \tag{10}$$

In line with Table 2 and formula 10, it can be acquired: that the rotation angle ratio of acceleration and deceleration shall be maintained about 3/2 in “rotating with full load” stage; the rotation angle ratio of acceleration and deceleration shall be maintained about 4/5 in “non-loaded rotating” stage.

5.2. MODEL OF OPERATING SKILL LEVEL ASSESSMENT

Intelligent auxiliary operation system can evaluate the skill level of the operator, on the one hand to assist the operator to correct bad operating practices, on the other hand it can be used as a staff performance appraisal reference. In the study, data of the time-spent and the corresponding rotation angle in rotation process was collected. The relationship between the rotation angle and time-spent of 500 groups of cycles has been acquired. As exhibited in Figs. 4 and 5, in line with the relationship, the operational level was split into 4 grades, specific calculation method including three steps:

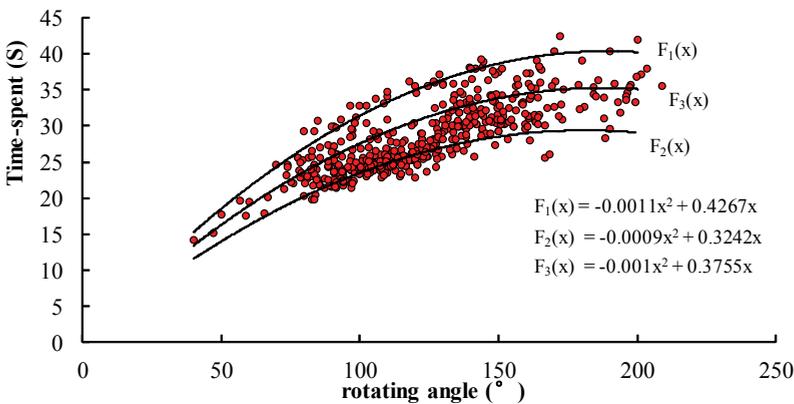


Fig. 4. Cartogram of the relationship between rotation angle and time in “rotating with full load” stage (maincut excavation & keycut)

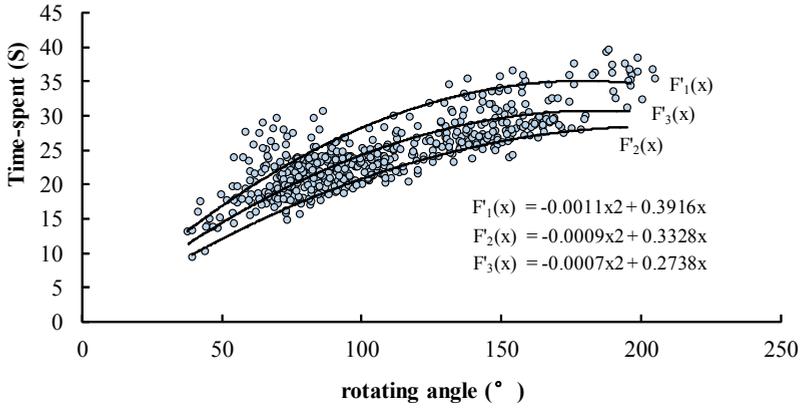


Fig. 5. Cartogram of the relationship between rotation angle and time in “non-loaded rotating” stage (maincut excavation & keycut)

- (1) Set a certain operation cycle as  $(\theta, t_i)$ , take  $10^\circ$  as the rotation angle range (such as  $50^\circ\text{--}60^\circ$ ,  $60^\circ\text{--}70^\circ$ ). The cycle time in each rotation angle interval can constitute a set respectively:  $T_1, T_1, \dots, T_j, \dots, T_m$ , and  $T_j = \{t_{j1}, t_{j2}, \dots, t_{ji}, \dots, t_{jm}\}$ . Set  $hight_j = 3/4 \sum_1^m t_{ji}$  and  $lowt_j = 1/4 \sum_1^m t_{ji}$ , it can be attained  $m$  of  $hight_j$  and  $m$  of  $lowt_j$ . Take  $\theta'_i$  as median (for instance, take  $\theta'_i = 55$ ) when rotating angle ranged from  $50^\circ$  to  $60^\circ$  of rotation angle range where the number sets placed,  $(\theta'_i, hight_j)$  and  $(\theta'_i, lowt_j)$  were fitted respectively. On that basis, two fitting curves of  $F_1(x)$  and  $F_2(x)$  were acquired. These two curves represented the approximate level of the optimal operation and poor operation set, respectively (Ma Xin-gen & Sun Jian-dong 2015; Sun Jian-dong et al. 2016).
- (2) Calculate the curve  $F_3(x)$  to split the area between the curve  $F_1(x)$  and  $F_2(x)$ , In this regard:
  - For  $\theta_i \leq F_2(t_i)$ , the operation cycle is defined as the first-grade operation;
  - For  $F_2(t_i) < \theta_i \leq F_3(t_i)$ , the operation cycle is defined as the second-grade operation;
  - For  $F_3(t_i) < \theta_i \leq F_1(t_i)$ , the operation cycle is defined as the third-grade operation;
  - For  $\theta_i > F_1(t_i)$ , the operation cycle is defined as the fourth-grade operation.
- (3)  $K$  is defined as comprehensive score of  $N$  times operations, and can be acquired via the formula:

$$K = 100/N (w_1 * N_1 + w_2 * N_2 + w_3 * N_3 + w_4 * N_4), \tag{10}$$

where:  $N$  is the total number of cycles;  $N_1, N_2, N_3, N_4$ , are operated times from first-grade to fourth-grade respectively and can be counted auto matically by sensors;  $w_1, w_2, w_3, w_4$  are the weights from first-grade to fourth-grade and we can take the valves in line with the specific requirements of the assignment. The weights in this study are 1, 0.9, 0.8, and 0.7.

5.3. DESIGN AND IMPLEMENTATION OF THE SYSTEM

The auxiliary intelligent operating system was encompassed by gyroscopes incorporated in smartphone and data acquisition software. The main program flow chart was illustrated in Fig. 6.

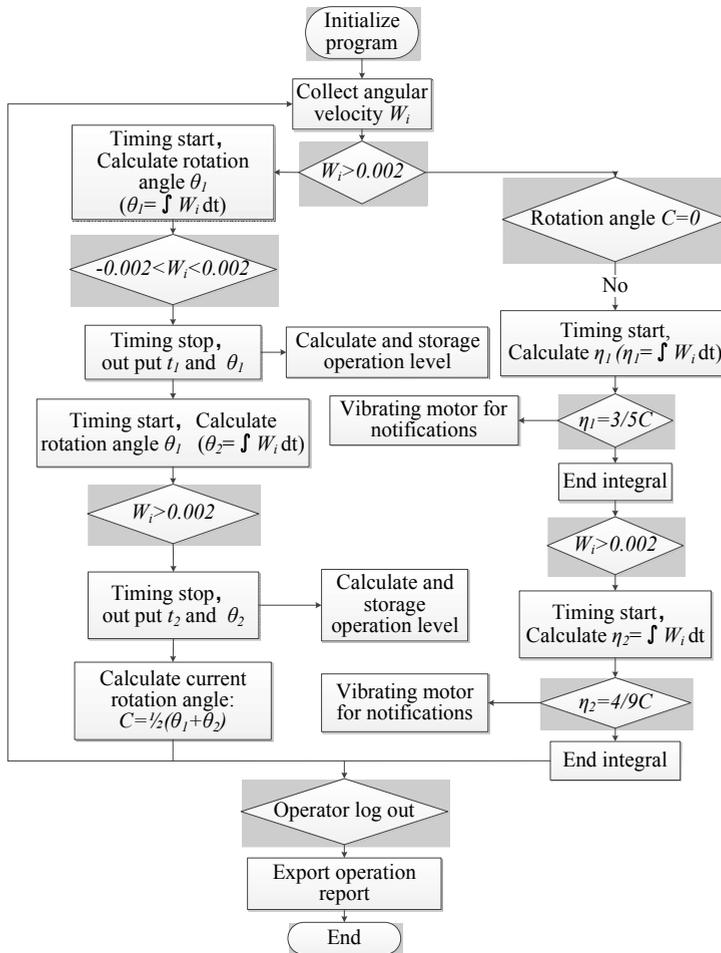


Fig. 6. Flow chart of the auxiliary intelligent operating system

### 6. FIELD TEST RESULTS AND ANALYSIS

To verify the effect of intelligent operation assistance system, the study carried out a field experiment. In the experiment, each operator operated 100 groups of operating cycles under the same operating conditions (maincutting mode). The prompt function of the auxiliary operating system was effectuated only in later 50 groups of operating cycles.

#### 1) Operating efficiency of the first 50 groups

Statistics of operator’s operation are exhibited in Table 3. In line with the results of the comprehensive score, it can be seen that the operating level presented  $A > C > B$ , and 50%–80% of the operating cycle reached the first-grade or second-grade operational level. Given the angular rate data sequence curves recorded by the operating auxiliary system, the reasons for the third-grade and fourth-grade operation were summarized in Table 3, the suggestions regarding operation elevation were given as follows: *A* shall easily mistake the early decelerate in the “rotating with full load” stage, and the acceleration time shall be increased appropriately. *B* often made the mistake of lagging decelerate in the deceleration phase of “non-loaded rotating” stage, and the acceleration time shall be shorten appropriately in the stage. Taking into account that the increase of time-spent caused by lagging deceleration is markedly in excess of the early deceleration, *C* shall increase acceleration time in “rotating with full load” stage and reduce the acceleration time in “non-loaded rotating” stage.

Table 3. Statistics of operator’s operation

Operator Grade		A	B	C
Grading statistics	first-grade	32	19	25
	second-grade	48	37	37
	third-grade	14	20	15
	fourth-grade	6	14	13
Average time and score	average time of cycle(s)	64.5	68.6	67.1
	comprehensive score <i>K</i>	90.6	78.1	79.4
Reason caused third-grade or fourth-grade operation	early deceleration	13	8	12
	lagging deceleration	3	24	10
	other reasons	4	2	5

#### 2) Operating efficiency of the latter 50 groups

Statistics of operator’s operation are exhibited in Table 4. In contrast with the first 50 groups of operation, the operators' faults in the operating process such as early deceleration, and lagging deceleration were markedly reduced. And about 90% of the

operating cycle reached the first-grade or second-grade operational level. The average time of operating cycle was shortened by 1–3 s. Experimental research was conducted under normal weather conditions, when there was rain, snow and low atmospheric pressure and other harsh conditions, intelligent auxiliary operating system could also effectively reduce the low-speed rotation, we can ensure that the full power operation of the dragline, the experimental comparison effect shall be more significant.

Table 4. Statistics of operator's operation

Operator Grade	A	B	C
First-grade	61	66	59
Second-grade	32	23	35
Third-grade	5	11	2
Fourth-grade	2	0	4
Average time of operating cycle (s)	63.2	63.0	63.8
Comprehensive score <i>K</i>	95.2	95.5	94.9

### (3) Problems and Prospects

In fact, results presented in Table 3 was collected under very ideal conditions. we found that dragline cycles were mainly swing-dependent, however, as digging got deeper, cycles became hoist-dependent. In particular, the materials near the bottom line of spoil pile had a low digging point and a high dumping point, so the dragline must rotate slowly to wait for the lifting process to finish. In addition, few some cycles were drag-dependent when the operators want to strip from a far point on the cut face. The use of gyroscopes could get better results when assist swing-dependent cycles than others.

In view of these situations, we think 3D images, laser modeling and other technologies should be used to determine the target location of digging and dumping point, then we could use the gyroscopes to control the rotating process, so as to obtain better auxiliary effects.

## 7. CONCLUSION

In order to elevate the skill level of the dragline operators, automatic acquisition function of dragline operation parameters was realized whereby smartphone sensors, and the operation level assessment criteria were quantified in line with the sensor data. A case study was conducted to compare the equipment efficiency changes before and after employing the intelligent auxiliary operating system. Conclusions were obtained as following:

1. Time-spent of dragline rotation process accounts for about 80% in operation cycle, and it is the key factor affecting the efficiency of equipment. Elevating skill level of dragline operators to shorten the cycle time saves stripping cost drastically.
2. Whereby the gyroscopes incorporated in smartphone, the real-time automatic collection of cycle time, rotation angle and other parameters in the process of dragline operation were achieved. Additionally, the problems existing in the operation can be grasped intuitively. In line with this method, the operating behaviors fall into 4 categories: the early deceleration, the lagging deceleration, the low speed operation, and the standard operation. The crux to elevate the cycle efficiency is to increase the proportion of the standard operating cycles to the total cycles.
3. The rotation angle ratio of acceleration and deceleration should be maintained about 3/2 in “rotating with full load” stage; the rotation angle ratio of acceleration and deceleration should be maintained about 4/5 in “non-loaded rotating” stage. On the basis of this, the auxiliary intelligent operating system was designed, which realizes prompt function of the equipment rotating operation and the assessment of operator’s skill level.
4. Field experiment results showed that after the application of intelligent auxiliary operating system, the operators’ faults in the operating process of the situation of early deceleration, lagging deceleration are markedly reduced. And about 90% of the operating cycle reaches the first-grade or second-grade operation level. The average time of operating cycle is shortened by 1–3 s.

In a nutshell, the application of intelligent auxiliary system is of critical importance in improving the efficiency of draglines. However, the dragline is one type of versatile large machines and its field operation conditions are complicated, in the paper merely the normal operations of the dragline are studied under standard operating conditions, the use of gyroscopes could get better results when assist swing-dependent cycles than others, so more operating conditions and complicated operating practices should be taken into account in the future studies.

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