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Research on Weighing System and Debugging Technology for Batching Under Blast Furnace Ore Tank

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Abstract: The article introduces the composition and working principle of the batching and weighing system underneath the blast furnace hearth. Besides, the shortcomings of the batching and weighing system during installation, debugging, and calibration, as well as the dynamic errors in the batching process are also analyzed. Corresponding solutions are then provided.

Keywords: Blast furnace hearth; Hopper scale; Calibration; Error correction

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1. Introduction

Material charging is one of the primary process systems of blast furnaces [1]. The weighing and control of the batching of various ores, coke, and other raw materials are crucial aspects in ironmaking. The rapid and accurate batching process has an essential impact on the efficiency and quality of blast furnace ironmaking.

In specific situations, a static batching method, such as employing a hopper scale, can be utilized [2]. In ironworks, the blast furnace batching system incorporates electronic hopper scales. Given that the feeding quantity directly impacts economic metrics, like the coke ratio and the smoothness of furnace operations, it plays a crucial role in cost reduction, energy savings, and minimizing energy consumption [3]. The weighing system under the blast furnace hearth is used to weigh the ore, raw materials, etc. Calibration is a critical step during the installation, commissioning, and usage of electronic scales, as it directly determines their accuracy. The traditional method of calibration is to use standard weights. However, this method is labor-intensive and inefficient. The accuracy of the measurement highly depends on the position of the weights. Improper placement of weights will lead to uneven load distribution and significant eccentric loads, can result in calibration failure and potential damage to load cells. It may even pose a safety hazard by causing collapses that could harm individuals..

The weighbridge scale weighing system for the ore bin is the main equipment for weighing materials below the blast furnace hearth. It is the core hardware that ensures accurate material distribution below the hearth. In the process of weighing and controlling the material supply below the blast furnace hearth, dynamic weighing error compensation has always been a major research topic in the direction of automation control of the blast furnace hearth material charging system.

In this case, ensuring both the construction progress and quality, as well as the safe installation, commissioning, and operation of weighing systems, is essential. Addressing dynamic control and compensation during material batching under the blast furnace hearth to eliminate dynamic errors is a critical challenge that needs immediate attention during on-site construction and commissioning.

2. Brief introduction of the batching system under the blast furnace tank

In the ironmaking process, solid raw materials such as iron ore, coke, and flux must be weighed and batched according to the process batching ratio of smelted products. The materials are then discharged batch by batch and finally sent into the blast furnace through the charging device at the top of the furnace for smelting.

A 1080 m^3 blast furnace of a steel plant will be used as an example. The blast furnace ore bins are arranged in a single row, with decentralized weighing, and materials are loaded onto the double cart inclined bridge. There are a total of 6 sinter ore bins, 2 pellet ore bins, 4 lump and miscellaneous ore bins, 2 coke bins, and 1 return ore bin, along with 2 coke nut bins and 2 coke powder bins in the storage area. The arrangement of the ore and coke bins, as well as the coke nut and coke powder bins, is symmetrically positioned to the left and right of the blast furnace. There are a total of 18 weighing hoppers, including 12 weighing hoppers under the ore bins, 2 concentrated weighing hoppers for ore and 2 concentrated weighing hoppers for coke in the material pits, and 2 weighing hoppers for coke nuts. There are 12 weighing hoppers under the mine trough, divided into left and right sides, and each side corresponds to a pit or centralized weighing hoppers. The primary function of the 12 ore weighing hoppers is to weigh the corresponding minerals according to the requirements and, simultaneously, discharge materials to the pit ore centralized weigh hopper according to a specific sequence. The 2 feed pit ore centralized weighing hoppers are used to weigh the total ore then send it to the top of the furnace through the feeding trolley. 2 pit coke weighing hoppers are used to weigh the coke. The coke is collected in the ore-weighing hopper in the pit and then sent to the top of the furnace by a feeding trolley.

The ore bin system has a total of 18 weighing hoppers, each supported by three resistance strain gauge-type load cells. They are equipped with compensation junction boxes to compensate for zero drift, temperature drift, and offset load of the load cells. The corresponding weight indicators are installed on the control room instrument panel, where they receive the direct current millivolt voltage signals (SIG+/SIG-) and convert them into standard current signals sent to programmable logic controller. The number and parameters of the weighing points are shown in **Table 1**.

3. Hopper scale weighing system

3.1. Working principle of hopper scale weighing system

The hopper scale comprises a weighing hopper, a load cell, a weighing junction box, and a weighing indicator (**Figure 1**).

The weighing hopper is designed to contain and convey the entire weight of the material being weighed onto multiple weighing sensors located between the weighing hopper and the foundation. When subjected to force, the elastic body inside the sensors undergoes deformation, causing a change in the resistance value of the internal strain gauges. Under the influence of the excitation voltage (EXC+/EXC-), this results in the generation

Table 1. The number and parameters of the weighing points

Location code	Weighing bucket name	Weighing range (t)
WE1101	Left coke nut weighing hopper	0–2
WE1102	1# Lump and miscellaneous ore weighing hopper	0–3
WE1103	2# Lump and miscellaneous ore weighing hopper	0–3
WE1104	3# Pellet weighing bucket	0–7
WE1105	4# Sintered ore weighing hopper	0–15
WE1106	5# Sintered ore weighing hopper	0–15
WE1107	6# Sintered ore weighing hopper	0–15
WE1108	Left pit ore weighing hopper	0–20
WE1109	Left pit coke weighing hopper	0–10
WE1110	Right coke nut weighing hopper	0–2
WE1111	7# Sintered ore weighing hopper	0–15
WE1112	8# Sintered ore weighing hopper	0–15
WE1113	9# Sintered ore weighing hopper	0–15
WE1114	10# Pellet weighing hopper	0–7
WE1115	11# Lump and miscellaneous ore weighing hopper	0–3
WE1116	12# Lump and miscellaneous ore weighing hopper	0–3
WE1117	Right pit coke weighing hopper	0–10
WE1118	Right pit ore weighing hopper	0–20

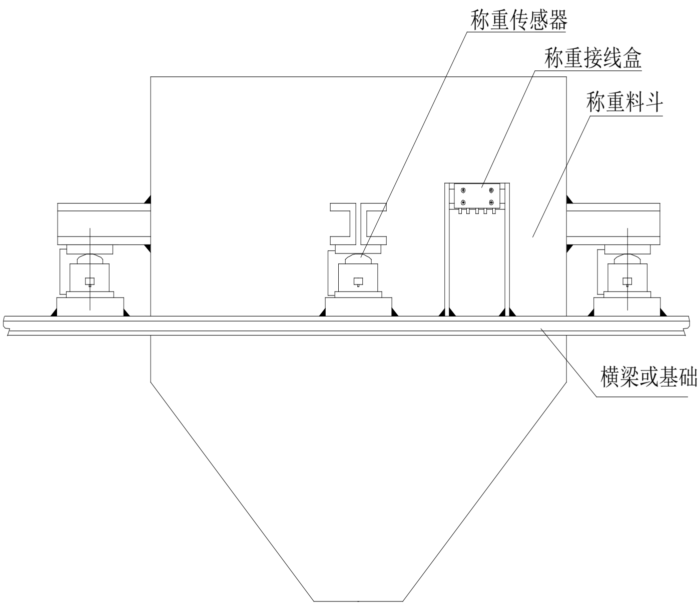

Figure 1. Schematic diagram hopper scale installation. Translation (from top to bottom): load cell, weighing junction box, weighing hopper, beam or base

of a direct current millivolt voltage signal (SIG+/SIG-) that is directly proportional to the weight of the material being weighed.

This voltage signal is then transmitted via shielded cables through the weighing junction box to the corresponding weighing display instrument or weighing module. Within the weighing display instrument or weighing module, the voltage signal is further amplified and converted by internal circuits into the corresponding weight display value. Simultaneously, the weighing display instrument outputs a 4-20mA standard current signal corresponding to the displayed value, which is sent to the PLC or other control units for automatic control of the weighing system. The wiring schematic diagram is illustrated in **Figure 2**.

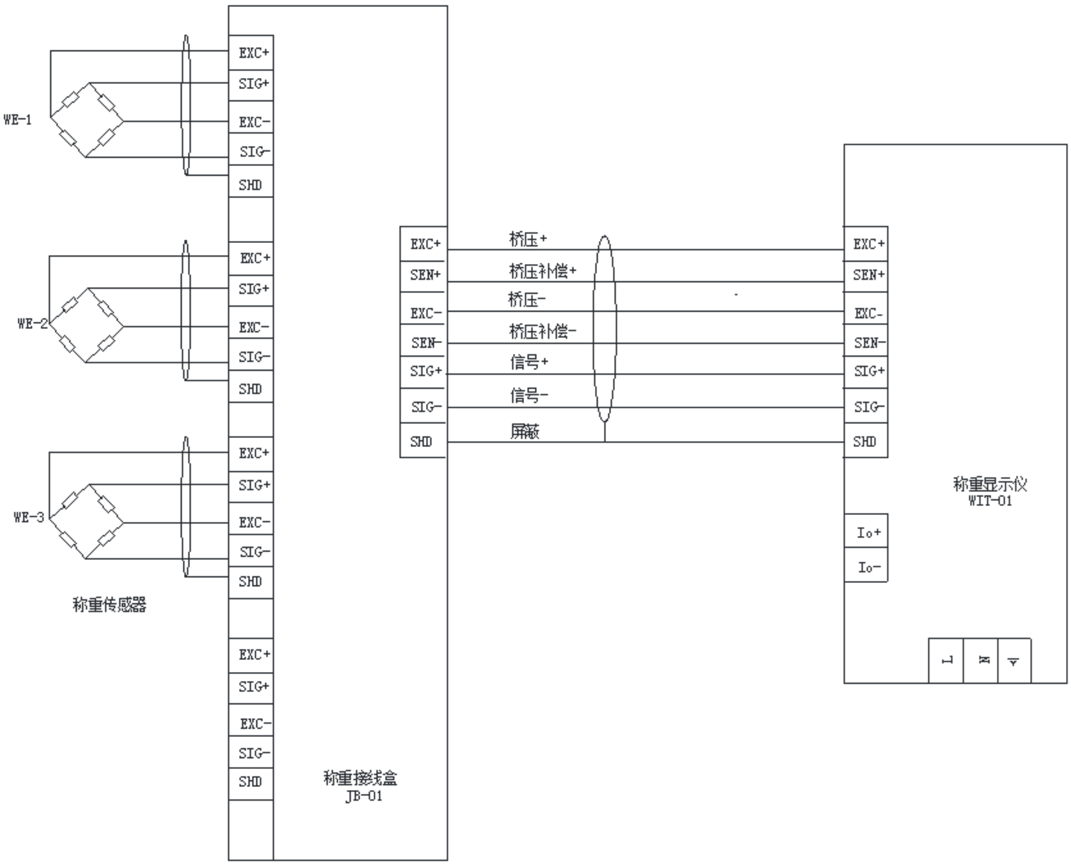

Figure 2. Hopper scale wiring scheme. Translation (from left to right, from top to bottom): weighing junction box JB-01, bridge voltage+, bridge voltage compensation+, bridge voltage-, bridge voltage compensation-, signal+, signal-, shielding, weighing indicator WIT-01

3.2. Static calibration of hopper scale weighing system

3.2.1. The working principle of the calibration device

During construction, the use of weighing hopper calibration devices with hopper-level detection instead of weights for calibrating the weighing hoppers ensures accurate measurement across the entire range of the hoppers. It not only guarantees precise weighing but also relieves employees from heavy labor, thereby improving work efficiency and reducing costs. The structure of the calibrating device is shown in **Figure 3**. Among these, the gantry frame is securely connected to the support beams or the foundation through welding or bolts. A hydraulic jack is installed vertically at the lower end of the central position of the horizontal beam of the gantry frame. The hydraulic jack is positioned vertically on top of the standard load cell used for calibration. Below the standard load cells for calibration is the pressure platform, and some padding is placed between the gantry frame and the hydraulic jack.

The structure of a magnetic level gauge is shown in **Figure 4**. Each magnetic level gauge is connected to each other through connecting hoses, forming a closed series of level gauges. The pressure platforms are individually positioned on the outer sides of the hopper's various sides, with each bracket arm extending outward horizontally toward the respective sides. The weight display instrument is configured with each standard weight transducer and is located at an area that is convenient for observing the results. The number

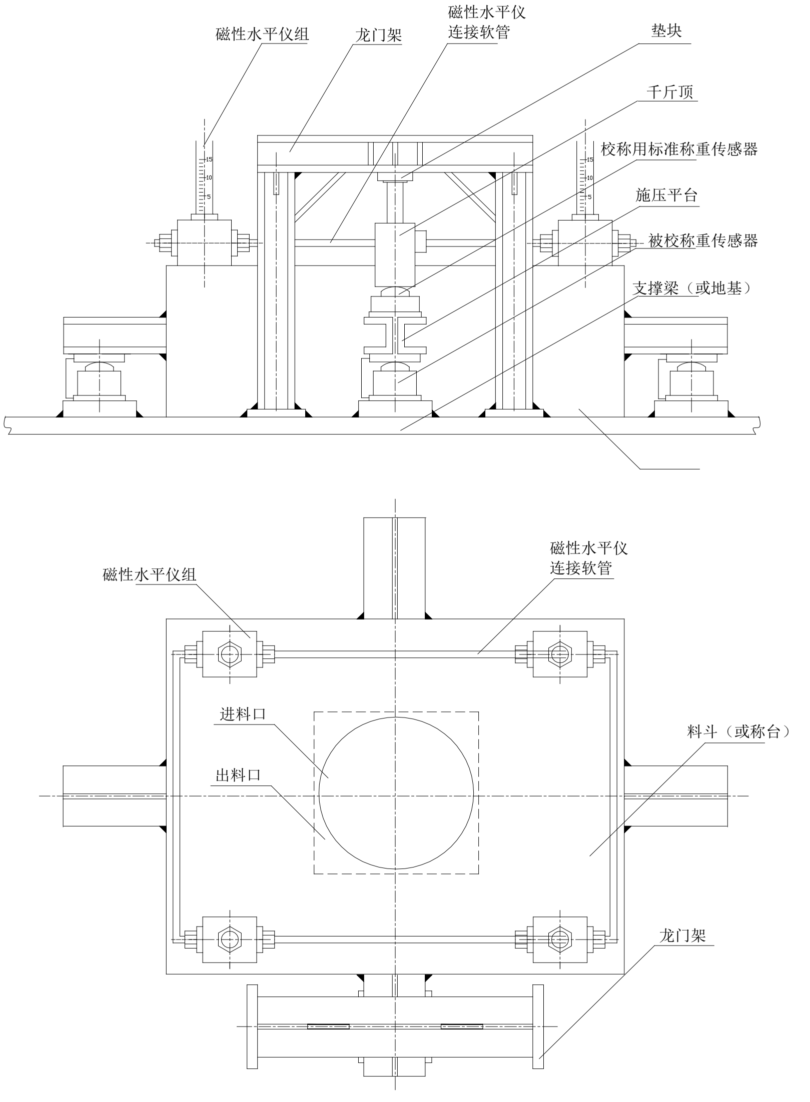

Figure 3. Structure of hopper scale calibrating device with hopper/silo level detection. Translation (from left to right, from top to bottom): magnetic level gauge assembly, gantry, connecting tube for magnetic level gauge, padding, hydraulic jack, standard load cells for calibration, pressure platform, calibrated load cells, supporting beam (or base); magnetic level, connecting tube for magnetic level, material inlet, material outlet, hopper (or weighing platform), gantry

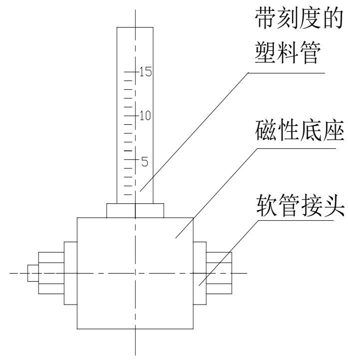

Figure 4. Structure of magnetic level gauge. Translation (from top to bottom): graduated plastic tube, magnetic base, hose connector

of sets of the calibration device corresponds to the number of weight transducers to be calibrated in the on-site hopper scale design. In **Figure 3**, only one set of devices is used as an example for illustration.

Before calibrating the electronic scale, the magnetic level gauge assembly, consisting of four magnetic level gauges, is positioned on the weighing hopper's horizontal plane so that it is evenly distributed at the corners. Water is then injected into the magnetic level gauge assembly via a scaled plastic tube using a funnel and a medical syringe. The hopper's levelness is assessed by monitoring real-time water level readings in each gauge. If any unevenness is detected, adjustments are made until the hopper is level. Next, the magnetic level gauges are removed from the weighing hopper, and zero-point calibration is conducted on the electronic scale. Then, the magnetic level gauges are placed back on the hopper's horizontal plane or evenly attached to the side of the metal weighing hopper at the same horizontal height to allow real-time observation during the loading process. The loading calibration can then be carried out.

During the loading process, the jack exerts upward force on the gantry, and the gantry forms the downward reaction force. The standard electronic scale composed of indicators can accurately display the pressure exerted by each jack and the total force exerted by all jacks. The setting of parameters setting of the central control unit can be performed by pressing specific buttons on the operation panel of the weighing indicator. The measured value of a particular sensor input channel will be displayed on a screen. The sum of the measured values of all sensor input channels will also be displayed. the number of standard load cells required is determined based on the actual number of load cells installed in the weighing hopper. These standard load cells are then connected to the respective sensor input channels on the weight indicator. The calibration device then converts the standard weights required for electronic scale calibration into conveniently applied standard mechanical forces. It accurately measures and serves as the standard load in place of weights, achieving the calibration of the weighing hopper. Additionally, by using four magnetic level gauges evenly positioned at the four corners of the hopper's horizontal plane, the horizontal alignment of the weighing hopper is continuously monitored in real time, preventing any occurrence of platform misalignment.

3.2.2. Individual calibration of load cells and weight indicators

Before installing the load cells and weighing display instruments, relevant inspections and calibration should be performed to determine their quality and accuracy. This is to prevent any delays in system commissioning. The key operational points for conducting the relevant inspections and calibration are as follows:

(1) Visual inspection

The appearance of the load cell to be calibrated and the weighing indicator is carefully observed. If the equipment is found to be damaged or deformed, it must not be used.

(2) Insulation resistance test

(i) The insulation testing is performed using the MΩ setting of a standard precision digital multimeter to check the insulation between the bridge supply voltage line (EXC+/EXC-) and the signal line (SIG+/SIG-) of both the load cell and the weighing indicator, as well as between the bridge supply voltage line (EXC+/EXC-) and the shielded wire (SHD), and, finally, between the signal wire (SIG+/SIG-) and the shielded wire (SHD).

(ii) The insulation status between the excitation voltage terminals (EXC+/EXC-) and the power supply terminals L/N, between the signal line terminals (SIG+/SIG-) and the power supply terminals L/N, as well as between the power supply terminals L/N and the grounding terminal of the weighing indicator should be checked using the MΩ range of a standard precision digital multimeter.

(iii) The resistance values between the load cell and the bridge supply voltage lines (EXC+ and EXC-) of the weighing indicator, as well as between the signal lines (SIG+ and SIG-), should be measured using the Ω file of a standard precision digital multimeter. These measured values should then be compared with the parameters provided in the product manual and technical data for verification.

(3) Individual adjustment of the weighing indicator

(i) After short-circuiting the EXC+ and SEN+ terminals, as well as the EXC- and SEN- terminals on the weighing indicator, the power cord should be connected to the weighing indicator according to the required working voltage (220VAC or 24VDC).

(ii) The weighing indicator is connected to a power supply, and a standard precision digital multimeter is used to measure the direct current voltage between the excitation voltage terminals (EXC+/EXC-) of the weighing display instrument. The accuracy and stability of the excitation voltage of the weighing indicator should be verified, ensuring it aligns with the technical parameters specified in the product's user manual.

(iii) The relevant parameters should be set according to the design process requirements, in conjunction with the operational steps outlined in the product manual of the weighing indicator, such as the instrument station number, measurement unit, and measurement range. During instrument calibration, preference should be given to the measuring range of a single load cell. Once instrument calibration is completed, the measuring range should be adjusted back to the required range as per the instrument design. For instance, if the weighing indicator provides a bridge supply voltage of 10VDC, and four 0–5t load cells are connected with a sensitivity of 2 ± 0.002mV/V and a corresponding output of 4–20mADC, the initial step in instrument calibration involves setting the weighing indicator's range to 0–5t (corresponding to a DC millivolt signal input of 0–20mV) and an output of 4–20mADC. Once all connected multi-channel load cells have been verified, the weighing indicator's range can be adjusted to 010t, with an output of 420mADC.

(iv) Using a high-precision standard signal generator, step 3 is taken as an example: DC signals of 0mV, 5mV, 10mV, 15mV, and 20mV are input. The corresponding display on the weighing indicator is 0t, 1.25t, 2.5t, 3.75t, and 5t, with the current output signal of the weighing indicator corresponding to 4mADC, 8mADC, 12mADC, 16mADC, and 20mADC. If the measured value or output signal exceeds the required accuracy range of the device or design, it should be adjusted according to the steps outlined in the product manual of the weighing indicator, and the calibration data should be recorded.

(v) The power supply is disconnected, and referring to Figure 3, a single load cell is connected directly to the corresponding terminal of the weighing indicator in preparation for load verification.

(4) Loading verification of weighing indicator and single-connected load cell

(i) A standard electronic scale, consisting of regularly calibrated high-precision load cells and corresponding weighing indicators (with an accuracy level one level higher than that required by the design of the electronic scale to be calibrated), is used. It is positioned using a gantry and jacks. Pressure tests are performed on the load cell to be calibrated (accounting for the weight of the load cell and the jack), and calibration is carried out at 25%, 50%, 75%, and 100% of the load cell's capacity. Each step (pressurization and depressurization) is executed at least twice, and adjustment records are simultaneously created during the calibration process. These adjustment records will be provided to the owner as part of the handover documentation.

(ii) The weighing indicator that has passed the calibration are labeled and the connected multi-channel load cells and mark the corresponding station number for easy installation [4-9].

4. Dynamic control in the batching process

4.1. Basic principle of ingredient weighing

The materials should be weighed within a specified time to ensure its accuracy. The process of weighing materials is an accumulation of material weight. If the quantity of already weighed material is denoted as *W*, the feeding rate as *V*, and the feeding time as *T*, the following relationships can be established

$$W = \int_0^T V dt \quad \cdots\cdots(1)$$

$$V = W' \quad \cdots\cdots(2)$$

Assuming that the set weight for the material is W_s, the difference from the set value is denoted as W_x. Initially, the material is fed at a speed of V_0. When the material weight reaches W_s–W_x, the time taken is denoted as t_l. Subsequently, the weighing speed *V* starts to decrease, and with the increase in the cumulative weight W, the weighing speed *V* gradually reduces until it approaches zero.

$$V = \frac{W_S - W}{n} \quad \cdots\cdots(3)$$

n is the rate of decrease in speed. That is to say, the feeding speed *V* is segmented according to the weighing weight, which can be represented by the equation below.

$$V = \begin{cases} V_0\,(\text{constant}) & W < W_S - W_X \\ \frac{W_S - W}{n} & W \geq W_S - W_X \end{cases} \quad \cdots\cdots(4)$$

When the cumulative descent of the material, denoted as W, has not reached W_s–W_x, the velocity control operates as a constant value adjustment system. However, when the cumulative material weight exceeds W_s–W_x, the velocity control switches to a dynamic adjustment system. While constant value adjustment is relatively straightforward, more emphasis is placed on the variable speed aspect. These relationships can be represented by equations (5)–(7).

$$W' + \frac{W}{n} = \frac{W_S}{n} \quad \cdots\cdots(5)$$

$$W = W_S - W_X e^{-\frac{t - t_1}{n}} \quad \cdots\cdots(6)$$

$$V = W' = \frac{W_X}{n} e^{-\frac{t - t_1}{n}} \quad \cdots\cdots(7)$$

According to formulas (6) and (7), the relationship curves of the cumulative amount (*W*) of the weighing material, the feeding speed (*V*), and the feeding time (*t*) can be drawn.

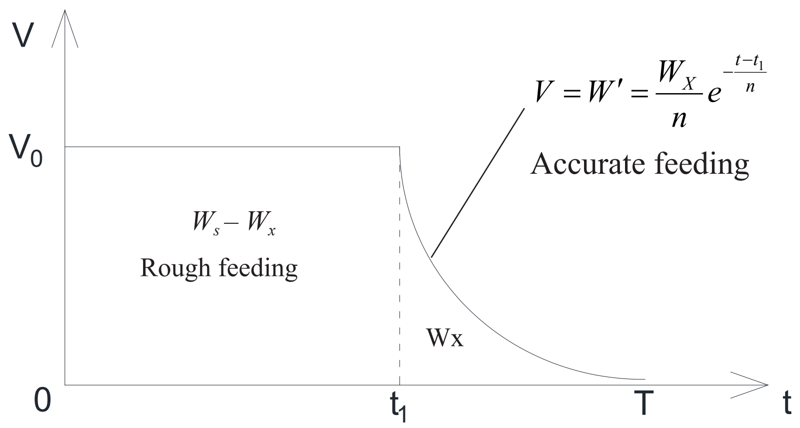

Figure 5. The relationship curve of the cumulative amount W of the weighing material, the feeding speed V, and the weighing time *t*.

It can be seen from **Figure 5** that the weighing speed (V) is continuously changing between 0 and $V_{0,}$ and W_x, and n are selected according to the characteristics of the weighing material. Proper selection of W_x and n can ensure the weighing speed. V depends on the weighing accuracy. However, it is important a suitable accuracy for weighing, or else and the weighing time will be prolonged, making batching process less efficient [10].

4.2. Dynamic error analysis of the batching process

The static error within the weighing hopper can be addressed in two ways. Firstly, by employing high-precision load cells and weighing indicators, so that the system's accuracy can surpass the precision required by the process batching, ensuring reliability. Secondly, periodic static calibration of the weighing system is conducted to ensure that its static error falls within the accepted range specified manual. However, during the material feeding process, factors such as the inertia of feeding devices and the material lag formed due to the height difference between the storage bin and the weighing hopper contribute to a delay in material discharge after the feeding machine is shut down. As a result, a portion of material continues to fall into the weighing hoppers, causing a discrepancy between the actual value and the instantaneous weighing value, as depicted in **Figure 6**.

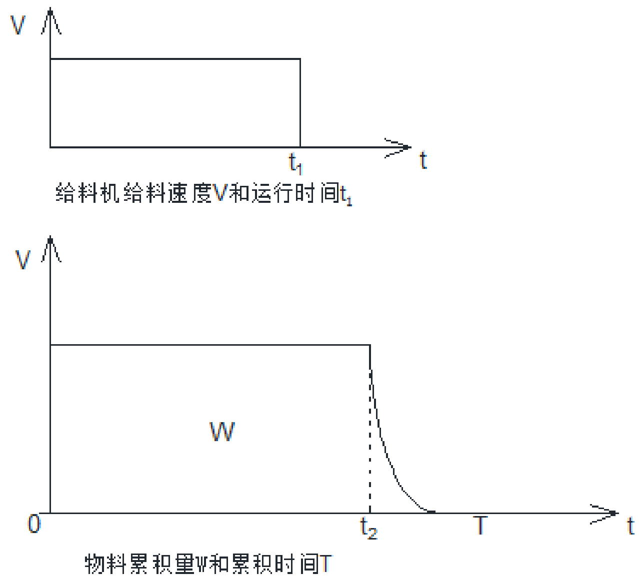

Figure 6. The relationship curve of cumulative weight (W), feeding speed (V), and weighing time (t). Translation (from top to bottom): feeding speed (V), and the running time (t_1) of the feeder, cumulative weight of material (W), and total weighing time (T).

Moreover, during the unloading process, there tend to be residual material due to the conical structure at the lower part of the hopper and variations in the size and moisture content of the material particles. These factors can lead to errors that accumulate over time, impacting the quality of ironmaking products and resulting in energy wastage if not dynamically controlled promptly. Therefore, before weighing the coke and the 12 ore weighing hoppers, it is essential to perform a series of calculations and corrections based on the set value (theoretical value determined according to the smelting process, known as the “dry value”). These corrections include moisture correction procedures (conducted using a neutron moisture meter), feeding error corrections, discharge error corrections, and more, all aimed at determining the actual weight accurately.

4.3 Dynamic error correction in the batching process

4.3.1. Feeding error correction

(1) Material preparation weight $W_{material\ preparation}$

Before weighing the hopper to prepare materials, firstly, according to the theoretical value W_{theory} of the ore required for the smelting process, and then combined with the weight that needs to be compensated for the previous weighing error, calculate the material preparation value W for this time.

$$W_{material\ preparation} = W_{theory} - \Delta W_{final} \cdots\cdots (8)$$

(2) Advance control of actual blanking value ($W_{material\ preparation}$)

After the feeding device, vibrating screen, and other components come to a halt, the mechanical inertia and the discharge hysteresis due to the height differential between the storage silo and the weighing hopper lead to a lag in the measurement value of the mine hopper scale’s weighing system. This lag can result in the actual discharge value exceeding the predetermined $W_{material\ preparation}$. To mitigate this situation, when the real-time measurement value from the hopper scale’s weighing system reaches $W_{control}$, the PLC sends a shutdown control signal to the feeding device in advance, so that the final weight of the blanking is within this time. within the allowable error range of the secondary material preparation value.

$$W_{control} = W_{material\ preparation} - W_{material\ preparation} \times (10\%\text{–}15\%) + W_{last\ remaining\ material} \cdots\cdots (9)$$

4.3.2. Compensation calculation of nesting error

When the material preparation is completed, the final weight W_{final} (the value corresponding to the hopper scale) can be obtained. Then, discharge rate will be automatically adjusted, and the weighing signal of the weighing hopper is monitored. When it detects that the discharge rate falls below a certain set value and the weight in the weighing hopper is low, it indicates the end of the discharge process and sends a signal to the electrical department to initiate the closing of the gate. After the gate is closed, the value of the empty hopper, that is, the weight of residual material, $W_{residue}$ (inevitably remaining in the hopper due to its conical structure, particle size, moisture, and other factors), is used for the weight correction (the principle of weighing correction is that the weighing error of this particular weighing hopper is compensated by this hopper and is not related to other hoppers). If the discharge rate is lower than a specific set value, but there is still a lot of material left in the weighing hopper, a discharge failure signal will be issued. In this case, it will not be read as $W_{residue}$. This particular weighing hopper will then be disabled until the fault is resolved.

$$W_{net} = W_{final} - W_{residue} \cdots\cdots (10)$$

$$\Delta W = W_{net} - W_{spare} \cdots\cdots (11)$$

After the first weighing, the batching deviation ΔW can be obtained, and then the batching variation of this time is used to correct the $W_{advance\ amount}$ of the following material preparation.

The first $W_{advance\ amount} = W_{material\ preparation} - W_{control} = W_{material\ preparation} \times (10\% - 15\%)$

$$W_{advance\ amount\ n+1} = W_{advance\ amount\ n} + \alpha \Delta W_n \quad (12)$$

ΔW represents ingredient deviation, α represents correction coefficient, with a range of $0 < \alpha < 1$

$$W_{complement\ n+1} = \Delta W_n$$

4.4. Debugging effect of dynamic batching weighing under the tank

Taking the coke batching scale (range 0–10*t*) in the left pit as an example, during the trial production, the first five batch weighing were tracked and recorded. The required batching amount of the first three batches of coke in the left coke tank was 8500kg/batch. The batching of the last two coke batches was 7500kg/batch, and the cumulative batching and weighing of 40500 kg was required.

When batching 8500kg for the first time:

The compensation weight ($W_{compensation\ 1}$) is 0. The material preparation value ($W_{material\ preparation\ 1}$) is equal to the theoretical value of the ore required for the smelting process, ($W_{theory\ 1}$), which is 8500 kg. The advance amount, ($W_{advance\ amount\ 1}$), is calculated as $W_{material\ preparation\ 1} \times 10\%$, which equals 8500 × 10% = 850 kg. The final weight ($W_{final\ 1}$) is 8521 kg. Since the material is empty and the remaining material is $W_{residue} = 30$ kg, the net weight ($W_{net\ 1}$) is 8491 kg. The batching deviation (ΔW_1), is calculated as $W_{net\ 1} - W_{prepared\ 1} = 8491 - 8500 = -9$ kg. When the second batching is 8500kg:

$W_{compensation\ 2}$ = batching deviation $\Delta W_1 = -9$kg, material preparation value $W_{preparation\ 2} = W_{theory\ 2} - W_{compensation\ 2} = 8500 - (-9) = 8509$kg.

$W_{advance\ amount\ 2} = W_{advance\ amount\ 1} + \alpha \Delta W_1 = 850 + 0.8 \times (-9) = 842.8$ kg ($\alpha = 0.8$). Because the material is empty and the remaining $W_{residue} = 42$ kg, the actual weight ($W_{final\ 2}$) is 8553 kg, and the actual unloading value $W_{net\ 2} = 8511$ kg.

The first to fifth batching weighing corrections can be deduced by analogy, and the results are shown in **Table 2**.

Table 2. Results of batching and weighing

Correction parameters	Weight of the first ingredient (kg)	Weight of the second ingredient (kg)	Weight of the third ingredient (kg)	Weight of the fourth ingredient (kg)	Weight of the fifth ingredient (kg)	Remarks
Theoretical weight, W_{theory}	8500	8500	8500	7500	7500	Cumulative 40500 kg
Material preparation weight, $W_{material\ preparation}$	8500	8509	8498	7478	7478	
$W_{compensation}$	0	-9	2	22	22	
$W_{advance\ amount}$	850	842.8	844.4	862	879.6	
Final weight, W_{final}	8521	8553	8550	7545	7526	
Residue weight, $W_{residue}$	30	42	30	45	38	
Weight deviation, ΔW	-9	2	22	22	10	
Net weight, W_{net}	8491	8551	8520	7450	7488	Cumulative 40510 kg
Accuracy (%)	0.25	0.52	0.61	0.89	0.64	0.12

It can be seen from the above table that through a series of error corrections, the influence of dynamic errors in the batch weighing process is well resolved, ensuring the accuracy and stability of the batch weighing.

5. Conclusion

Calibrating the hopper scale using its fast calibration device, instead of traditional weight loading makes the calibration process much more efficient and less labor-intensive. Besides, it guarantees accurate measurements across the hopper scale's entire range. This method liberates construction personnel from strenuous labor, boosting efficiency, and cost savings. Furthermore, it addresses dynamic weighing errors during batching under the blast furnace hearth by proposing a compensation and control scheme, ensuring stable, efficient, and accurate weighing and control for blast furnace batching.

Disclosure statement

The author declares no conflict of interest.

References

[1] Xu A, Zhao J, 2011, Optimal Control Algorithm for Feed Weighing Under Blast Furnace Trough. Metallurgical Automation, 2011(6): 34.

[2] Zhang Y, 2006, Analysis of the Accuracy of Batching Scale System. Journal of Chifeng University, 2006(1): 39.

[3] Qin H, 2001, Analysis and Application of Maintenance and Calibration Methods of Hopper Electronic Scale. Measurement and Testing Technology. 2001(1): 17

[4] Le J, 2002, Instrument Worker's Handbook (2 Edition) [M]. Beijing: Chemical Industry Press.

[5] Xu L, 2002, Practical Electrical Engineer's Handbook (Volume 2), Guangzhou Science and Technology Press, Guangdong.

[6] General Administration of Quality Supervision, Inspection and Quarantine of the People's Digital Indicating Scale Verification Regulations, JJG539-2016, viewed August 29, 2023.

[7] Ministry of Industry and Information Technology of the People's Republic of China, 2013, Construction Technical Regulations for Petrochemical Instrument Engineering, SH/T 3521-2013, viewed August 29, 2023.

[8] Ministry of Housing and Urban-Rural Development of the People's Republic of China, and General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Code for Construction and Quality Acceptance of Automation Instrumentation Engineering, GB50093-2013, viewed August 29, 2023.

[9] Ji H, Zheng Y, Ren B, et al., 2011, Hopper Scale Calibration Device and Method with Hopper or Silo Level Detection, 2011101569196, Chinese Patent.

[10] Wang C, Bai Z, Hang B, 2002, Establishment of Mathematical Model of Feeding Speed. Electronic Measurement Technology, 2002(1): 5–6.