Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 13, No. 1, 2024

Design of an Automatic Powder Dosing Control System Based on Dual ARM Core

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Abstract: In industries such as pharmaceutical, petrochemical, and food processing, automated powder doses are increasingly favored over traditional manual methods due to their higher productivity and accuracy. Despite the advances in existing technologies, challenges such as weighing accuracy, cost and limited secondary development capabilities remain. This paper presents an automated powder dosing control system based on a dual ARM core architecture. By using dual ARM core processors, the system enhances the hardware architecture and control flow to achieve accurate powder weighing. The experimental results show that the average errors of three kinds of powders with different physical properties are 0.089g, 0.012g, and 0.054g respectively, which meet the design specifications.

Keywords: Dual ARM Core; Weighing Precision; Control System; Automatic Dosing.

1. Introduction

The primary process of powder dosing involves the automatic weighing, distribution of various powders, and mixing of raw materials according to preset formulations. This technique is widely employed in industries such as pharmaceuticals, petrochemicals, and food processing [1,2]. Current Production and Experiments In current production and experimental settings, traditional manual weighing and dosing present several disadvantages, including low efficiency, poor precision, and potential harm to human health from some powdered medications. With the advancement of modern industrial and manufacturing technologies, the demand for automatic powder dosing machines is continually increasing [3–5]. Current research on automatic batching machines concentrates on enhancing precision and reliability within the automation process, while also aiming to reduce costs and boost scalability[6].

Yang et al [7]developed a PLC-based system for the automatic batching of powder materials, designed to mitigate problems such as dust emissions, leaks, environmental pollution, and health risks. Central to this system is a buoyancy weighing sensor used for precise measurement. Nonetheless, the initial investment required for PLC systems is substantial, and their potential for secondary development is notably constrained. Shandybina et al [8] enhanced the control system of a universal automatic weighing and batching machine, substantially boosting the efficiency and accuracy of batching granular food ingredients, albeit with a complex control process. Building on this foundation, the paper presents a structurally simple, user-friendly, and highly accurate automatic batching machine control system. The design specifications include:

(a) Precise measurement of powder materials with a tolerance of less than 0.1g.

(b) An integrated PC interface facilitates data monitoring, storage, recipe management, and alarms throughout the batching process.

(c) According to the predetermined recipe, it can automatically and continuously complete the entire batching process and is conveniently designed for secondary development to expand functionalities.

2. System Solution Design

The automatic batching machine adheres to the automation principle of "centralized control, decentralized management[9,10], as depicted in Fig.1, It consists of five components: a weighing system, inspection and cleaning unit, upper-level and lower-level computers, and a communications module. Users enter the types and weights of powder ingredients needed for recipes via the upper-level computer's PC interface. Communications between the upper and lower computers are facilitated through an Ethernet link. The lower-level computer, featuring dual ARM processors, manages the operation of motors, pumps, sensors, and other electrical components using RS-485 and SPI communications, along with high-speed pulse signals, to handle weighing, mixing, and subsequent cleaning tasks.

The weighing system, as a core component of the batching machine, directly influences its performance through its degree of automation, precision, and reliability, and is crucial for the accurate formulation of medications and the development of drilling fluids[11,12]. The structure of the weighing system of the automatic dosage machine is shown in Fig. 2, Powder materials are initially stored in bins and transported for dispensing through the coordinated movement of motor-driven transfer and hopper mechanisms. The loading motor adjusts the powder flow via a worm gear setup, while materials are precisely weighed by sensors beneath the hoppers. After reaching the designated weight, the hopper rotates to a preset zero point for controlled discharge by the unloading motor. Each bin resets after unloading powder materials, preparing the system to process the next powder type. Once all ingredients are collected, they are combined in a mixing tank. A servo motor powers the transfer and hopper mechanisms throughout the process, enabling the smooth transfer of powder materials between loading and unloading units and ensuring both automation and precise control.

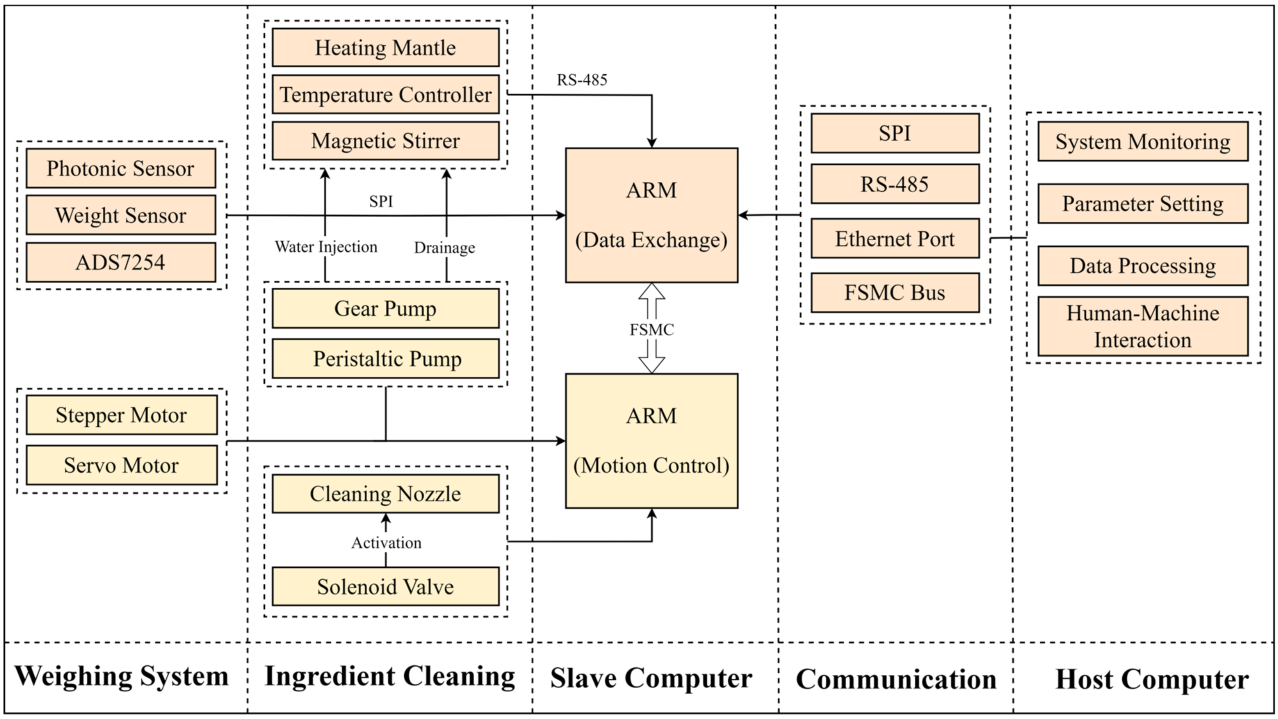
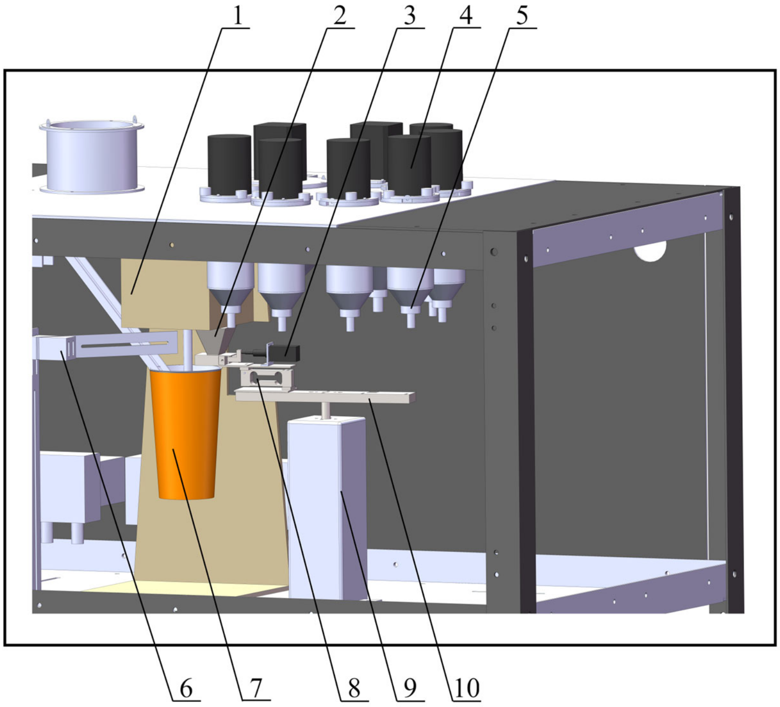


Figure 1. System solutions



food mixer 2- hopper mechanisms 3- Unloading motor 4- Loading motor
5- Powder canisters 6- Photoelectric sensors 7- Configuration tanks 8- Weighing sensors
9- Servo motor 10- transfer mechanism

Figure 2. Weighing system structure

3. Hardware Circuit Design

3.1. Dual ARM chip master control circuit

The system requires a high-performance controller due to the large number of electrical components and high computational load, which can lead to resource wastage and excessive costs. To address this, the core control board utilizes dual ARM chips, boosting computational efficiency while reducing costs. As illustrated in the system diagram (Fig 1) and main control circuit (Fig 3), a “master-slave” control configuration is employed: the primary chip oversees data exchange and communication, while the secondary chip is responsible for motion control, including motor speed regulation, start-stop control, and power conversion throughout the circuit.

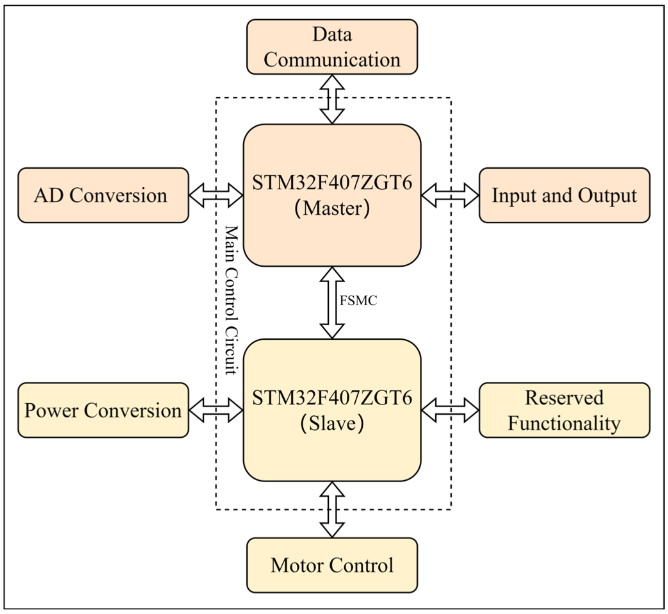


Figure 3. Main control circuit

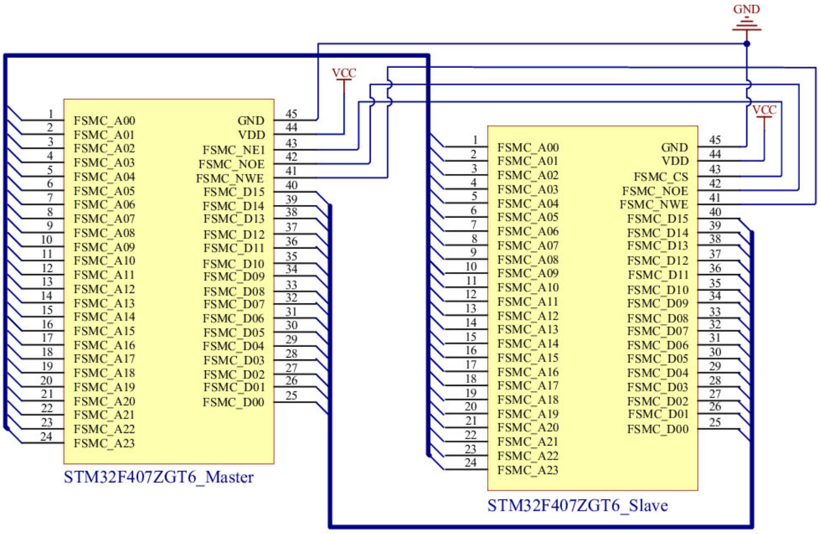


Figure 4. Dual ARM communication

The dual ARM chips communicate using FSMC-based dual-machine communication on STM32F407 processors, with both control unit chips being STM32F407ZGT6 models. The master ARM chip (STM32F407ZGT6_Master) maps the SRAM memory of the slave ARM chip (STM32F407ZGT6_Slave) into its own memory space, enabling data transfer through read-write operations within this mapped area. This method provides high transmission speed, ideal for high-speed data exchange. [13]. The STM32F407ZGT6_Slave is mapped to the FSMC bank1 PSRAM of the STM32F407ZGT6_Master with a capacity of 16MB. The chip select signal is FSMC_NE1, with data transfer on lines FSMC_D00 to FSMC_D15 and an address range of 0x6C000000 to 0x6FFFFFFF. Address lines FSMC_A00 to FSMC_A23 are used, and the system operates on a 3.3V power supply, as shown in Fig 4.

3.2. Motor Control Circuit

This system involves servo and stepper motors working in tandem with the mechanical structure, and with photoelectric sensors for closed-loop control of the rotation angle and displacement to ensure operational accuracy and efficiency, ensuring automation and precise control of the system. In addition, the system is designed with gear pumps for water injection and peristaltic pumps for cleaning, further reflecting the complexity and importance of motor control. Therefore, the logic control of multiple motors is not only the core of the hardware drive but also a key factor in the overall performance and reliability of the system.

The stepper motor circuit schematic is shown in Fig. 5. The differential line driver DS26LS31CM, converts the control signals into differential signals to improve the immunity to interference.CP1, CP2, DIR1, and DIR2 are the control ports used to control the starting, stopping, and direction of the motor. The P1 and P2 connectors are connected to the motor driver to control the motor operation. The "point1" and "point2" are used as external interrupt inputs to allow the STM32 to respond instantly to critical events in motor operation, monitor states such as rotational speed or position, and achieve precise control of the motor. In addition, pull-up resistors are included in the circuit to ensure that the optocoupler outputs are pulled high when the transistors are turned off, in order to match the input level requirements of the motor driver.

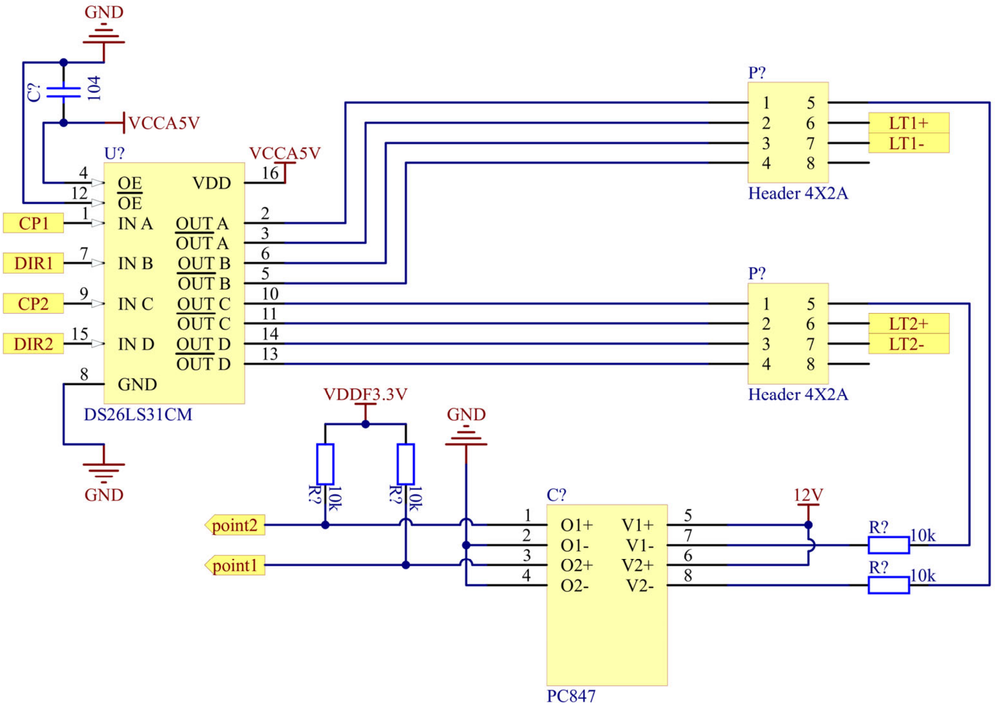
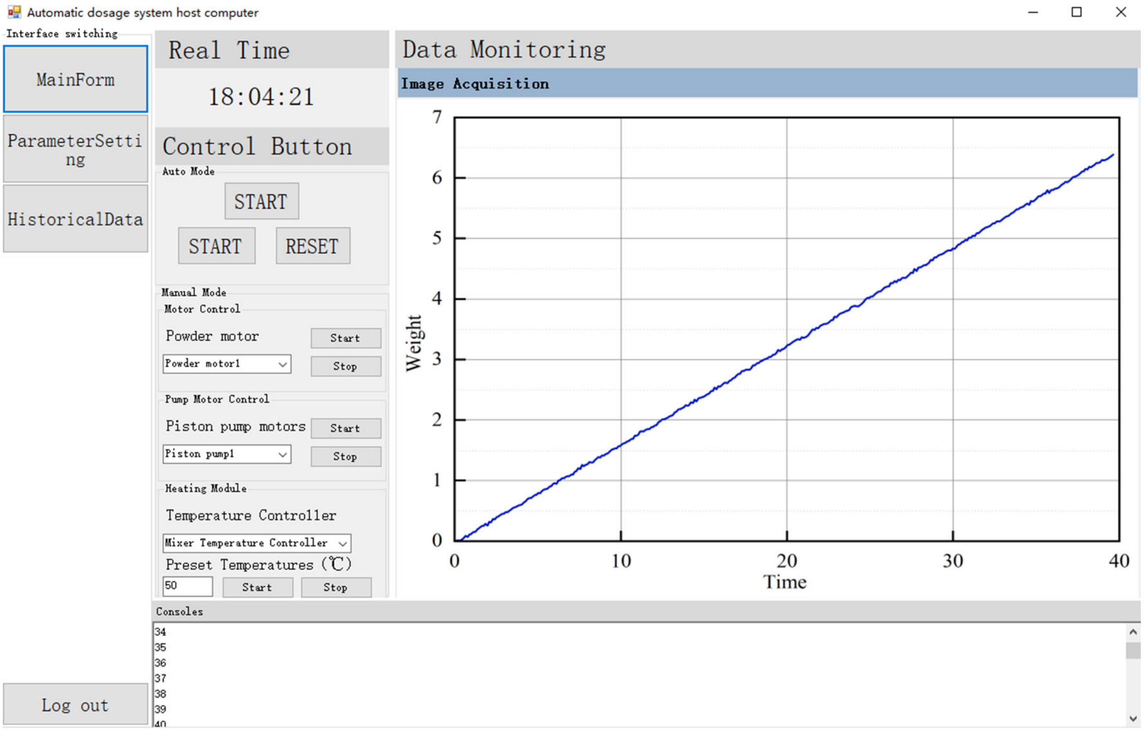


Figure 5. Motor circuit crinciple

4. System Software Design

4.1. PC interface design

The PC software interface, as shown in Fig 6, includes several functional modules: parameter settings, real-time monitoring, data monitoring, and controls for the motor and heating modules. There are two operation modes: manual and automatic. In manual mode, motors are started and stopped directly through manual control buttons. In automatic mode, however, motor start and stop actions are governed by the software's logical flow to achieve coordinated multi-motor operation.



Powder motor1

Piston pump1

Mixer Temperature Controller

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35
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Figure 6. PC interface

4.2. Automatic control mode

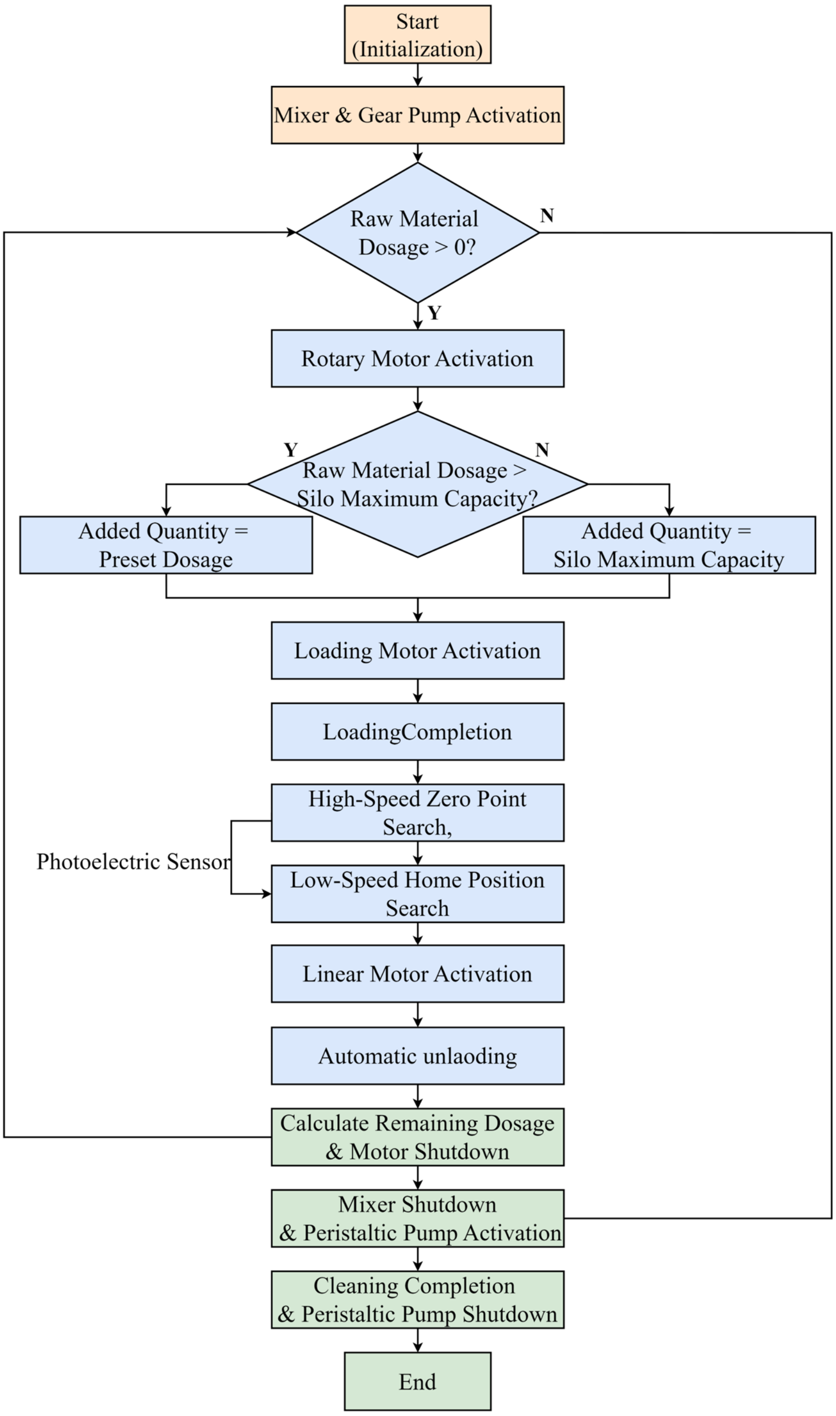
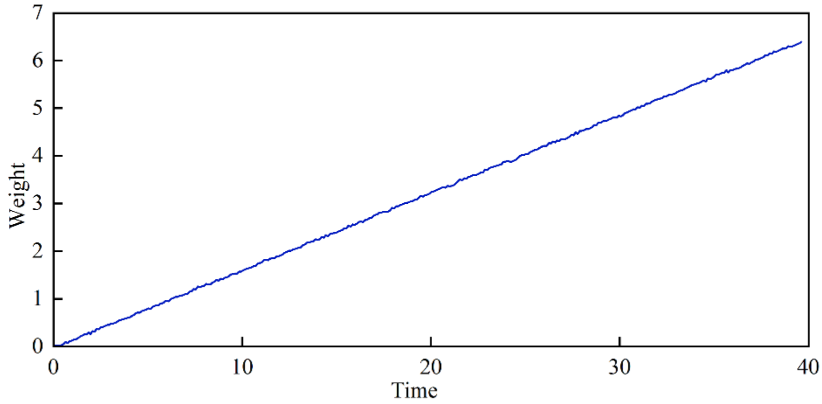


Figure 7. Automatic control mode

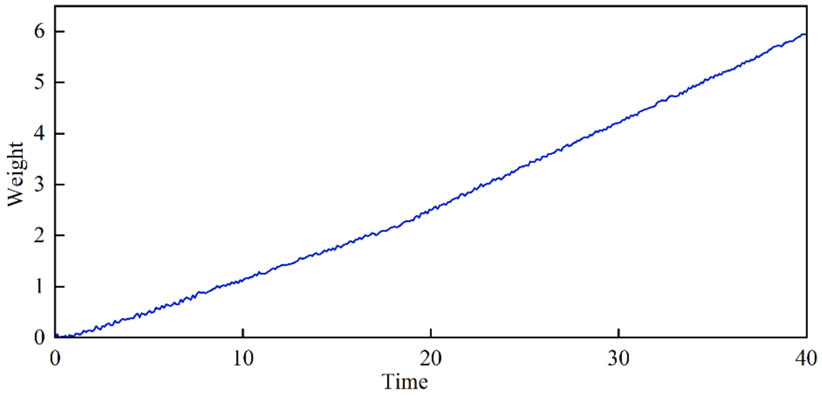
This system's automatic motor control procedure flow is shown in Fig 7, the first stepper motor drive function controls the motor start and stop, so that the mixer and gear pump start; the bin loading capacity detection function is responsible for controlling the weight of powder raw materials parameters, comparing the dose of raw materials with the maximum loading capacity of the silo, more than the maximum loading capacity needs to be divided into a number of times loading. The loading and unloading process has a preset point, the bin rotary reset function to control the rotary motor to drive the weighing bin and photoelectric sensors with the return to zero and reset, and finally the cleaning function to complete the cleaning process.

5. Empirical Test

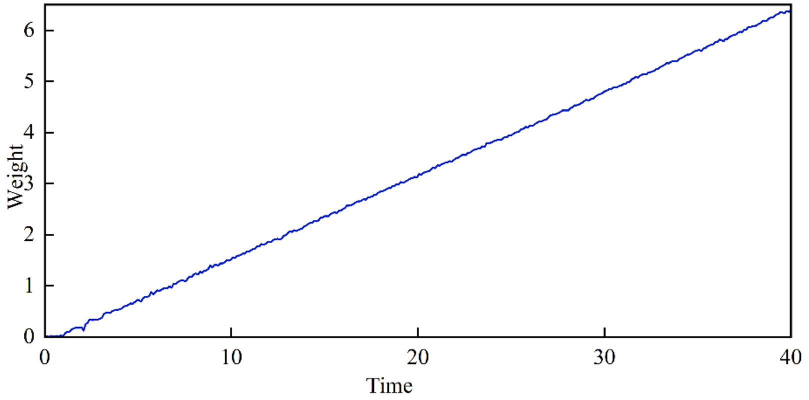
To assess the overall performance of the automatic batching control system, three types of powder materials with varying densities, particle sizes, and friction coefficients were selected. The powder drop time was set to a fixed 40 seconds on the upper-level computer, and weight and time data were recorded. As illustrated in Fig 8, the graph appears smooth and exhibits exceptional stability. Compliance with design requirements



(a) Podwer1



(b) Podwer1



(c) Podwer1

Figure 8. Weight-Time Images

A high-precision electronic scale (accurate to 0.001g) was used to measure the actual total weight of three types of powder materials after 40 seconds of descent, comparing this with the collected data. As shown in Table 1, the results indicate the actual weights of each powder type and their respective errors. For Powder 1, the error ranged from 0.085g to 0.091g; for Powder 2, it was smaller, between 0.009g and 0.015g. Powder 3 exhibited more variation, with errors spanning from 0.046g to 0.064g. The average errors for Powders 1, 2, and 3 were 0.089g, 0.012g, and 0.054g, respectively, all below the 0.1g threshold, satisfying the design specifications.

Table 1. Results of powder weighing experiments

Number	powder1		powder2		powder3	
	Actual/g	Inaccuracies/g	Actual/g	Inaccuracies/g	Actual/g	Inaccuracies/g
1	6.300	0.090	6.010	0.010	6.870	0.049
2	6.350	0.088	6.112	0.015	6.909	0.056
3	6.290	0.085	6.123	0.013	6.876	0.046
4	6.410	0.091	6.145	0.009	6.890	0.064

Figure 9. Powder discharging site of automatic batching machine

6. Conclusion

This paper presents the design and implementation of a dual-ARM core-based automatic powder batching control system, aimed at addressing the high cost and limited scalability of traditional automatic batching machines. The system employs a “master-slave” dual-ARM core configuration, with the primary chip responsible for data exchange and communication, and the secondary chip managing motion control. This configuration optimizes motor control logic, lowers development costs, and facilitates secondary development, enhancing scalability. With a high level of automation, the system leverages precise coordination between motors and sensors to achieve significant improvements in batching accuracy. Experimental results confirm the system's high accuracy and repeatability when processing powders with various physical characteristics, with batching errors maintained below 0.1g. These innovations enhance the system’s cost-effectiveness and usability, providing valuable insights for the design of similar automated systems.

References

[1] Saasen A. Automatic Measurement of Drilling Fluid and Drill-Cuttings Properties[J]. 2009. .

[2] Lysyannikov A, Kondrashov P, Pavlova P. Means and Method for Measurement of Drilling Fluid Properties[J]. IOP Conference Series: Materials Science and Engineering, 2016, 132: 012014.

[3] Yamazaki Y, Shigematsu K, Kato S, et al. Design method of material handling systems for lean automation—Integrating equipment for reducing wasted waiting time[J]. CIRP Annals, 2017, 66(1): 449-452.

[4] De Oliveira Hansen J P, Da Silva E R, Bilberg A, et al. Design and development of Automation Equipment based on Digital Twins and Virtual Commissioning[J]. Procedia CIRP, 2021, 104: 1167-1172.

[5] Sun B, Jämsä-Jounela S-L, Todorov Y, et al. Perspective for equipment automation in process industries ∗ ∗This work is based on research supported by the project (No. 296432), Towards sustainable mineral processing via plantwide eMPC, Mineral Resources and Material Substitution-MISU, 2014-2019 Int. call for joint projects in mineral resources research, South Africa and Academy of Finland, project 5G meets Industrial Internet financed by Technology Industries (No. 3102144), the National Natural Science Foundation of China project (No. 61603418), the 111 Project (B17048), the National Research Foundation of South Africa (IRC grant number 103666).[J]. IFAC-PapersOnLine, 2017, 50(2): 65-70.

[6] Chyzhykov D, Widziewicz-Rzońca K, Błaszczak M, et al. Automatic weighing system vs. manual weighing precision comparison in PM-loaded filter measurements under different humidity conditions [J]. Environmental Monitoring and Assessment, 2023, 195(11): 1393.

[7] Yang X, Kong L, Wang Y, et al. Control of Powder Material Automatic Batching System based on PLC[J]. Journal of Physics: Conference Series, 2019, 1213(5): 052095.

[8] Shandybina I M, Makarov A M, Kukhtik M P. The Development and Study of a General-Service Automatically Controlled Weighing Batcher[C]. Radionov A A, Gasiyarov V R, eds.//Proceedings of the 7th International Conference on Industrial Engineering (ICIE 2021). 2022: 270-277Cham: Springer International Publishing, 2022: 270-277.

[9] Yang J, Liu Q, Li C, et al. Online adaptive SHE algorithm for multilevel converters and implementation with embedded control system[J]. Energy Reports, 2023, 9: 1190-1202.

[10] Yang R, Wang S, Liu S, et al. Design of a control system for rotating equipment[J]. Computers & Chemical Engineering, 2024, 180: 108499.

[11] Yamazaki T, Sakurai Y, Ohnishi H, et al. Continuous mass measurement in checkweighers and conveyor belt scales[C]//Proceedings of the 41st SICE Annual Conference. SICE 2002. 2002, 1: 470-474Osaka, Japan: Soc. Instrument & Control Eng. (SICE), 2002: 470-474.

[12] Pietrzak P. FAST FILTRATION METHOD FOR STATIC AUTOMATIC CATCHWEIGHING INSTRUMENTS USING A NONSTATIONARY FILTER[J]. 2009(4). .

[13] Cui M, Lu L, Zhang Z, et al. A Laser Scanner–Stage Synchronized System Supporting the Large-Area Precision Polishing of Additive-Manufactured Metallic Surfaces[J]. Engineering, 2021, 7(12): 1732-1740.