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# Practical Design of Coin Measurement Equipment Based on Virtual Simulation Technology

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**Abstract:** Coin circulation plays a fundamental role in daily consumption and commercial settlements across various civilian scenarios. Traditional coin weighing equipment development has heavily relied on physical prototypes for repeated calibration, suffering from chronic issues such as slow R&D progress, excessive testing costs, and limited adaptability to diverse operational environments, thereby failing to meet practical standards for multiple application scenarios. With practicalization of coin weighing devices as the core research focus, virtual simulation technology has been integrated throughout the development process. This approach establishes a comprehensive lifecycle design and validation framework, clearly defining the design logic, technical implementation methods, and deployment plans. Through virtual modeling combined with simulation testing and continuous iterative improvements, common defects in legacy equipment, including material jamming, measurement accuracy errors, and insufficient anti-counterfeiting recognition precision, have been effectively addressed. The overall structural design, operational functions, and performance of the equipment have undergone holistic enhancement and upgrading.

**Keywords:** Virtual simulation technology; Coin weighing equipment; Simulation modeling; Equipment design; Measurement accuracy

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## 1. Introduction

The development of traditional coin weighing equipment typically follows a fixed workflow: "physical modeling–prototype fabrication–debugging and refinement." This process requires repeated refinement of physical prototypes, consuming substantial human and material resources while making it difficult to promptly identify structural defects and performance shortcomings during debugging. Consequently, such equipment often suffers from prolonged development timelines and limited adaptability to diverse operational scenarios, failing to flexibly meet varying coin weighing requirements. Virtual simulation technology offers core advantages of visualization, interactivity, and iterability, enabling device model construction and operational scenario simulation within virtual environments. This allows early identification and mitigation of design flaws while optimizing equipment performance. This paper focuses on the practical application of virtual simulation technology in coin weighing equipment design, breaking free from traditional design constraints to achieve efficient, precise, and practical solutions, thereby providing actionable insights for similar weighing equipment development.

## 2. Relevant theoretical and technical foundations

### 2.1. The core connotation and application logic of virtual simulation technology

Virtual simulation technology integrates expertise from multiple disciplines, including computer graphics, virtual modeling, and dynamic simulation. Its core principle involves creating computer-generated virtual models that closely replicate physical entities, enabling the simulation of operational states, force characteristics, and functional behaviors to facilitate equipment design, debugging, refinement, and validation. Unlike traditional physical prototyping methods, virtual simulation eliminates the need for physical prototypes, allowing multi-scenario, multi-parameter simulation testing within virtual environments to identify design flaws swiftly and enable iterative improvements. The application process consists of three interconnected phases, virtual modeling, simulation analysis, and iterative refinement, that form a closed-loop system ensuring both scientific rigor and practical feasibility of design solutions. In metrological equipment design, this technology accurately reproduces coin motion trajectories, coordinated component operations, and measurement performance under various operating conditions, providing robust support for structural design and parameter optimization.

### 2.2. Core structure and working principle of coin measurement equipment

The feeding module systematically arranges randomly scattered coins and feeds them into the equipment's internal structure, minimizing material accumulation and processing delays. The conveying module ensures smooth material transfer through its belt-and-roll mechanism, with coin flow synchronized to the operational rhythm of downstream functional units. The authentication module captures physical characteristics such as coin dimensions and material composition, distinguishing denominations while eliminating counterfeit coins. The counting module records identified coin data for precise quantity measurement of each denomination, while the sorting module classifies coins by face value and stores them in designated compartments [1]. All functional units operate in seamless coordination, enabling automated coin measurement. The modular design and parameter configuration directly determine the equipment's operational efficiency and measurement accuracy.

### 2.3. Compatibility between virtual simulation and coin measurement equipment design

The core of coin weighing equipment design lies in addressing practical challenges such as material jamming, measurement deviations, and inaccurate authenticity verification. Virtual simulation technology effectively addresses the limitations of traditional designs, demonstrating exceptional compatibility between the two approaches. The equipment's modules feature complex structures with stringent precision requirements for component interactions. By employing accurate modeling to replicate component motion trajectories and interlocking mechanisms, virtual simulation enables early identification of potential issues like component interference or improper clearance, eliminating the need for repeated adjustments during physical prototyping. Coin motion is influenced by multiple parameters, including conveying speed and component angles. Virtual simulation allows the simulation of coin behavior under various operating conditions through parameter optimization, refining critical parameters like conveying speed and component orientation to enhance operational stability and measurement accuracy. This technology facilitates rapid design iteration without requiring repeated physical prototyping, significantly reducing design costs and development timelines while better meeting the diverse application requirements of coin weighing systems.

# 3. Design process for coin weighing equipment based on virtual simulation technology

## 3.1. Construction of the virtual simulation model

The construction of virtual simulation models forms the foundation for coin weighing equipment R&D, fully replicating all core components and functional units of the physical equipment. The accuracy of model reproduction directly determines the reference value of simulation data. Performance standards for the equipment are established based on real-world application conditions, with definitive specifications for overall architecture, component parameters, and material selection. The design aligns with actual operational requirements, and professional simulation software enables layered model construction, comprising independent component rendering, structural assembly, and operational environment replication. Critical components such as feed hoppers, conveyor systems, detection/sensing modules, and sorting actuators are reproduced at a 1:1 scale to physical specifications, with material properties and mechanical parameters synchronized into the system. Individual components are assembled and calibrated according to real-world assembly logic, with fine-tuning of clearance and interlocking mechanisms to eliminate operational risks caused by structural interference.

## 3.2. Simulation scenario construction and parameter tuning

The configuration of simulation scenarios and parameter tuning directly determines the effectiveness of overall performance optimization for coin counting equipment. By replicating the actual operating environment and dynamically adjusting key parameters, structural design flaws are identified, enabling continuous improvement of the equipment's operational performance. Utilizing virtual modeling, multiple simulation environments are created to cover common operating conditions such as varying coin quantities and mixed currency dispensing, fully reproducing the equipment's real-world operational state. Core metrics, including conveying speed, feeding angle, sensor recognition sensitivity, and sorting component operation frequency, are integrated into a unified parameter system, with initial value ranges established based on actual coin counting operational conditions. The counting unit consists of sensors and an iris mechanism. Coins pass through a dedicated counting channel from the distribution plate to the packaging cylinder, where a photoelectric counter measures their quantity; the count is displayed on the upper screen of the machine's outer packaging. When the specified coin capacity or its multiple is reached, the iris mechanism closes to halt coin entry and update the packaging cylinder, after which the mechanism opens to resume coin packaging and collection [2].

## 3.3. Simulation result analysis and preliminary optimization

The data collection scope encompasses coin circulation efficiency, measurement accuracy, anti-counterfeiting identification performance, and component wear patterns. After a comprehensive analysis of integrated data, the equipment's existing design strengths and latent weaknesses are clearly identified. All operational issues are systematically categorized, with root causes traced through mechanical operation principles: structural defects in the feeding hopper or excessive conveying speed led to material blockages, while improper sensor placement or parameter imbalances result in measurement inaccuracies. By addressing these root causes, refining model specifications, optimizing feeding area surfaces to reduce coin accumulation at inlets, recalibrating sensor positions for stable physical feature acquisition, and enhancing sorting mechanisms, the operational stability and sorting efficiency have been significantly improved.

# 4. Practical design, optimization, and refinement of coin measurement equipment based on virtual simulation technology

## 4.1. Practical verification of virtual simulation design

The implementation validation of virtual simulation design focuses on aligning optimized virtual solutions with real-world application scenarios, evaluating the feasibility and practical value of the overall solution, and minimizing discrepancies between simulation outcomes and actual equipment performance. Using the refined virtual model, a small-scale experimental prototype was developed and subjected to field tests with mainstream coin types and diverse deployment conditions. Critical parameters, including prototype operational status, measurement accuracy, and material handling efficiency, were comprehensively documented [3]. Measured data were compared with simulation results to identify discrepancies. Unconsidered factors during virtual modeling, such as material wear and environmental interference, could cause actual performance deviations from predicted outcomes. By analyzing these discrepancies, model parameters were refined, simulation environments detailed, and real-world influencing factors (e.g., material wastage and external disturbances) incorporated. The overall equipment design was continuously improved through iterative calibration.

## 4.2. Simulation-based device performance optimization

Simulation-based performance optimization constitutes the cornerstone for enhancing the practical value of coin counting devices. By integrating simulation analysis with field test feedback, targeted improvements are implemented to address operational shortcomings, thereby comprehensively elevating system stability, measurement accuracy, and operational efficiency. At the structural level, design details were refined to resolve issues such as material blockages and component interference observed in both simulations and field tests. The feeding unit features curved transition channels to minimize coin obstruction during transit, while precise calibration of roller spacing in the conveying unit ensures smooth coin movement without misalignment. The sorting unit's architecture was further optimized to improve classification speed and precision. Regarding operational performance, critical parameters were refined to address measurement deviations and authentication failures, including enhanced sensor detection logic, a multi-sensor collaborative detection system for improved currency identification and anti-counterfeiting capabilities, and optimized counting algorithms that reduce measurement errors and ensure accurate data output.

## 4.3. The application value and promotion applicability of virtual simulation technology

The coin weighing equipment design developed using virtual simulation technology overcomes the inherent limitations of traditional R&D approaches, fully unleashing its overall application value and adoption potential. The entire development process eliminates the need for repeated prototyping and adjustments, enabling rapid iteration of design solutions while significantly reducing development timelines and maintaining reasonable cost control. This effectively addresses common issues in conventional R&D models, such as excessive trial-and-error cycles and slow development rhythms [4]. During the early stages of equipment prototyping, simulation tools allow early identification of structural flaws, ensuring continuous improvement in operational performance and measurement accuracy, thereby guaranteeing long-term stability and compliance with all industry standards. This approach substantially reduces modifications and rework during physical assembly and debugging. After implementation, model parameters can be flexibly adjusted for various operational environments, enabling rapid adaptation to diverse scenarios, including bus stop change counting, supermarket daily settlements, and self-service terminal currency processing. The equipment demonstrates exceptional compatibility and flexibility, making this innovative design framework applicable to similar weighing instrument development. It provides actionable references for creating precision measurement devices for small objects, driving the modernization of traditional industry R&D systems toward higher-quality, refined operational paradigms.

# 5. Conclusion

This paper focuses on the practical application of virtual simulation technology in the design of coin weighing equipment. Addressing the various shortcomings inherent in the R&D phase of traditional coin weighing devices, the study integrates virtual simulation into the entire design process, establishing a comprehensive R&D framework encompassing "virtual modeling–simulation debugging–practical validation–optimization and refinement." This approach enables holistic design and iterative improvements to the coin weighing equipment. Research confirms that virtual simulation effectively mitigates the inherent limitations of conventional design methodologies, reduces development timelines and trial-and-error costs, enhances operational stability, measurement accuracy, and practical value, while effectively resolving common challenges such as material jamming, measurement deviations, and counterfeit identification issues. The coin weighing device proposed in this paper features a clear structural logic and a highly implementable design that can be directly deployed across various weighing scenarios, while providing actionable insights and technical references for similar equipment development. Due to current research constraints, the design's adaptability under extreme environments requires further validation. Future efforts will involve refining the virtual simulation model, incorporating simulation testing for extreme conditions, and optimizing equipment design details to improve overall compatibility and operational reliability, thereby advancing the deeper integration of virtual simulation technology in metrological equipment design.

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## Disclosure statement

The authors declare no conflict of interest.

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