

Iron Ball Launcher Platform Control System for Impact Test at Glass Testing Laboratory

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Abstract

This study presents the digital transformation of a glass impact test system at the Center for Standardization and Services for the Ceramic and Non-Metallic Mineral Industry (BBK) through Industry 4.0 integration. The legacy system faced challenges including manual distance measurement, outdated safety components, mechanical momentum causing positioning inaccuracy, and inability to sequentially launch multiple iron balls. To address these, a phased approach was implemented: analysis, design, implementation, and testing of a digital control system. Key upgrades included LIDAR-based wireless distance sensing (up to 9 meters), RS-485 communication for reliable data transfer, replacement of 1980s-era fuses with modern Mini Circuit Breakers, and algorithmic compensation for mechanical delay. A microcontroller-based control system enabled automated height adjustment, mode selection per national standards, and sequential ball release. The system was tested across six height settings with five trials each, achieving an error rate below 1% in all cases. Results confirm enhanced precision, safety, and efficiency. This targeted digitalization demonstrates how Industry 4.0 technologies can modernize legacy testing equipment without full replacement, offering a cost-effective, scalable model for industrial laboratories undergoing digital transformation.

Keywords: *industry 4.0, glass testing lab, micro controller*

Abstrak

Studi ini memaparkan transformasi digital sistem uji dampak kaca di Pusat Standarisasi dan Layanan Industri Keramik dan Mineral Non-Logam (BBK) melalui integrasi Industri 4.0. Sistem lama menghadapi tantangan termasuk pengukuran jarak manual, komponen keamanan yang usang, momentum mekanis yang menyebabkan ketidakakuratan penempatan, dan ketidakmampuan meluncurkan bola besi secara berurutan. Untuk mengatasi hal ini, pendekatan bertahap diterapkan: analisis, desain, implementasi, dan pengujian sistem kontrol digital. Peningkatan utama meliputi sensor jarak nirkabel berbasis LIDAR (hingga 9 meter), komunikasi RS-485 untuk transfer data yang andal, penggantian sekering era 1980-an dengan pemutus sirkuit mini modern, dan kompensasi algoritmik untuk penundaan mekanis. Sistem kontrol berbasis mikrokontroler memungkinkan penyesuaian ketinggian otomatis, pemilihan mode sesuai standar nasional, dan pelepasan bola secara berurutan. Sistem diuji pada enam pengaturan ketinggian dengan lima uji coba masing-masing, mencapai tingkat kesalahan di bawah 1% dalam semua kasus. Hasil menunjukkan peningkatan presisi, keamanan, dan efisiensi. Digitalisasi terarah ini menunjukkan bagaimana teknologi Industri 4.0 dapat memodernisasi peralatan uji warisan tanpa penggantian penuh, menawarkan model yang hemat biaya dan skalabel untuk laboratorium industri yang menjalani transformasi digital.

Kata kunci: *industri 4.0, laboratorium pengujian kaca, mikrokontroler*

1. Introduction

The term Industry 4.0 was introduced around 2011 by a group of scientists from Germany. The authors lay out their vision of how the integration of digital technologies, the Internet of Things (IoT), and artificial intelligence (AI) can revolutionize the manufacturing industry and create highly automated and connected smart factories. They also outline the challenges that must be faced to realize this vision, including security, interoperability, and standards issues.[1]

Even though it has been introduced for a long time, the digital transformation that is promised as an implementation of industry 4.0 in the real world is still in the development phase. Many organizations are in the process of adapting their operations to integrate new technologies, while facing challenges such as updating legacy systems, upskilling the workforce, and ensuring cybersecurity. As a result, the journey towards a fully digitized industrial landscape continues to evolve, requiring continuous investment and strategic planning.

The Center for Standardization and Services for the Ceramic and Non-Metallic Mineral Industry (BBK) is one of the organizations that seeks to implement Industry 4.0 technology. BBK promotes the use of Industry 4.0 by equipping their test facilities with digital technology. Digital technologies help BBK update their legacy systems, enable integration with new technologies, and optimize work processes.[2]

Previously, BBK had applied digital technology in the tile deformation laboratory. This technology converts statistical process control data into a serial format. With this conversion, legacy systems can connect directly to a computer network system without the need for manual data logging. In addition, this conversion system has been upgraded to wireless, allowing simultaneous measurement from five sensors at once.[3]

One of the test tools that has undergone digital transformation through vocational applied research activities is the impact test ball launcher platform used in glass laboratories. This applied research carried out allows the tool, which was previously manually operated, to be upgraded with digital technology to improve the precision and efficiency of testing. This transformation not only enables the automation of the testing process, but also provides the ability to collect and analyze data in real-time, resulting in more accurate and reliable results for the evaluation of the strength and durability of glass materials.

2. Material and Method

The research that will be carried out will take place in several well-structured stages to ensure the success of digital transformation in test tools. Each stage is designed to identify and address challenges, as well as ensure that the new digital control system can function optimally.

Our research methodology is built on a foundational belief: that successful digital transformation hinges on the thoughtful integration of robust engineering with a deep understanding of human factors. Consequently, our approach is not a linear checklist but a cohesive, four-phase process designed to bridge the gap between technical possibility and practical usability.

A. Phase 1: Groundwork: System Analysis and User Discovery

We will begin by building a deep, contextual understanding of the current operational landscape. This involves a two-pronged investigation. First, we will conduct a rigorous technical audit of the existing test apparatus, examining its mechanical limitations, software performance, and documented procedures to establish an objective performance baseline.

However, this technical data alone is insufficient. To bring this data to life, we will conduct a series of in-depth, semi-structured interviews with the system's daily users—the operators and technicians. The goal here is to move beyond assumptions and uncover the lived experience of using the tool: their frustrations, their clever workarounds, and the subtle inefficiencies that SOPs fail to capture. This qualitative approach is crucial for identifying the "pain points" that a purely technical analysis would miss and ensures that our subsequent design efforts are focused on solving real-world problems.

B. Phase 2: From Insight to Blueprint: A User-Centered Design Process

Armed with a clear understanding of the challenges and opportunities, our next step is to translate these requirements into a tangible design. This phase is fundamentally collaborative and iterative. We will develop the core system architecture, selecting hardware and software components designed for reliability, security, and scalability.

Crucially, before a single line of code is finalized, we will engage users in a critical feedback loop. We will present low-fidelity prototypes and interface mockups to our user group, asking them to walk through key tasks. This step serves as an early "reality check," allowing us to test the intuitiveness of the workflow and validate our design choices. By inviting feedback at this conceptual stage, we can make meaningful adjustments cheaply and quickly, ensuring the final design is not just technically sound but also genuinely user-friendly.

C. Phase 3: Bringing the Design to Life: Implementation and Integration

This is where the digital blueprint meets the physical world. With a user-validated design in hand, our team will proceed with the development and implementation of the digital control system. Working shoulder-to-shoulder with site engineers, we will install the new components and meticulously integrate them with the existing mechanical hardware. This phase involves careful calibration and initial functional testing to ensure all parts of the new, hybrid system communicate seamlessly and perform as a unified whole.

D. Phase 4: The Final Test: Performance Validation and Real-World User Acceptance

The final phase serves as the ultimate arbiter of success. A system must first be technically sound, so we will subject it to a battery of stress tests and performance benchmarks to verify its accuracy, stability, and reliability under a range of operational conditions.

But its ultimate success is determined by the people who use it. Therefore, the capstone of our methodology is formal User Acceptance Testing (UAT). We will invite the same group of end-users to perform their daily tasks on the newly implemented system. Through direct observation and post-session interviews, we will assess whether the new system is not only functional but also a marked improvement. We will be looking for measurable gains in efficiency, reductions in error rates, and qualitative feedback on user confidence and satisfaction. This final evaluation ensures that the delivered solution is both powerful and practical, marking the successful completion of the digital transformation.

By going through these stages, the research is expected to produce a digital control system that not only improves the efficiency and accuracy of the test equipment, but also makes a significant contribution to the development of technology in related industries.

3. Results and Discussion

The following are the results of observations of the system that has been running at the BBK Glass Impact Test Laboratory. An illustration of the test system is shown as shown in Figure 1. In this system there is an iron ball (A) that will be launched from the top of a glass (B) of a certain height. The height of the iron ball is obtained by raising and lowering the launcher platform (D) using a chain (C). The chain is driven by a 1 ϕ phase AC motor.

The electrical power for the control of the equipment in this test comes from a 110V AC voltage source. This voltage is obtained by lowering the standard voltage of 220V AC to 110V AC using a step-down transformer.

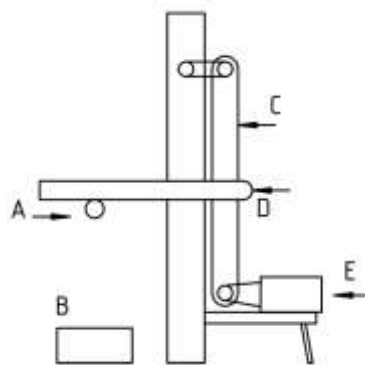


Figure 1. Illustration of Glass Impact Test System in BBK

This 110V AC voltage is used to drive the AC motor. This motor rotates the chain gearbox that lifts the iron ball release platform. The height of this platform must be controlled so that it has a certain distance from the glass object being tested in accordance with national standards. There are several types of glass and there are several discharge distances that must be considered in the manufacture of the platform control system.

The up and down of the platform is currently controlled through a panel as seen in **Figure 2**. The left knob is to lower the platform while the right knob is to lower the platform. When raised, the platform does not immediately stand still in position when stopped. As a result of using the chain, the platform still has momentum to move until it finally completely stops.



Figure 2. Platform Up and Down Control Panel

The iron ball is held on a platform using magnets. The radius and weight of the iron balls used are three. In addition to the large iron ball, there are mannequins that are also released through the same magnet. Small iron balls are placed on a sleeve that has a release mechanism that keeps other iron balls from slipping. Currently the iron ball holding mechanism does not work so each ball needs to be removed one by one to test the glass.

Based on these existing conditions, several problems can be identified. The first problem is the measurement of the distance between the iron ball and the glass object. At this time, it is still using a roll meter. These roll meters although their size is calibrated every year, they still need to be observed directly near glass objects. Because there are iron balls that are carried to a certain height from the glass surface, this condition can be dangerous for test workers.

The second problem is the fact that the platform drive motor is still supplied with 110V power, we find that the supporting system also still uses old technology. For example, the overcurrent safety part still uses a fuse from the 1980s as seen in **Figure 3**. At this time, it can be confirmed that this model fuse is no longer on the market so it must be modernized.



Figure 3. Collision Test System Safety Fuse

The third problem is the altitude control process that still uses chains to get up and down the platform. This altitude control has a slow response and still depends on the momentum of the platform's movement. When the control system stops the power supply to the motor, the platform does not stop immediately but rather runs a little longer until it completely stops because there is momentum in motion. This condition requires handling the controls so that the platform completely stops in the desired position.

The fourth problem is the control process of the iron ball launch, which cannot be sequenced more than one. As a result, the iron ball release platform had to be raised many times for each test that required a lot of iron balls. This kind of work is inefficient so it needs to be assisted with a ball release that can carry more than one ball and release it one by one.

Once all the problems have been identified, the next step is to design a solution that can solve the problem. The most appropriate solution is indeed to use a modern system as suggested by [4]. But to replace the entire system will take a long time and a huge cost. Therefore, only part of the system will get updates with the addition of industry 4.0 features.

Industry 4.0 can help solve the first problem by providing a digital system based on Single Board Computers or microcontrollers. With this system, a more flexible, independent, dynamic, and also precise system will be obtained [5,6].

One of the problems faced was the measurement of the distance from the iron ball release platform to the glass surface. The test has several different distance sizes depending on the type of glass and the application. The longest distance to be measured is nine meters. There aren't many sensors, especially wireless ones, that can be used to measure distances that far.

There are at least two sensors that are popularly used to measure distances wirelessly. The two sensors work using ultrasonic and LIDAR principles. Some researchers have compared the performance of the two in transportation applications such as in [7–9]. In general, researchers agree that LIDAR has better accuracy compared to ultrasonic, especially for relatively long distances.

Industrial-grade LIDAR sensors are hard to find in the local market. Moreover, sensors that have the ability to measure distances that are far enough up to nine meters as needed. The two sensors available are the 50m distance sensor and the 12m mini-TF LIDAR. Both have quite good accuracy. For example, what has been researched using [10] mini-TF LIDAR obtained 99% accuracy with a distance of up to nine meters. In addition, the best accuracy is also obtained by using a blue reflector.

But there is another problem: the results of LIDAR measurements must be readable from the control panel that is more than three meters away from the system in Figure 1. If you use a cable directly from the sensor to the meter reader controller, it is feared that it will cause a reading error. Therefore, it is necessary to add a reliable communication system for data transmission. The communication system chosen is RS 485 whose components are widely available in the market as is usually done in industrial meter readings. The RS 485 can be used to communicate between two microcontrollers as done by [11] and [12].

Since glass is not a good reflector for LIDAR, the placement of the sensor needs to be considered. This placement option falls in a position at the bottom of the system near the motor. The LIDAR sensor will shoot at the iron ball release platform that moves up and down. On this platform is pasted blue paper to provide better light reflection results so that distance measurements are more accurate.

For the second problem, system security that still uses old technology can be upgraded to new technology. A fuse made in the 80s can be replaced with a Mini Circuit Breaker. The part of the system that is susceptible to overcurrent is the AC motor. So, the MCB used will pay attention to the operating parameters of the AC motor. The implementation of this update is shown in **Figure 4**.



Figure 4. Fuse Renewal with MCB

The third problem where the platform stops once the momentum is exhausted needs to be circumvented by adding more or less value to the control program. With this addition, the motor stopping process is carried out before the platform reaches the desired position. The platform will actually stop at the predetermined position even if there is momentum delaying its stop.

The fourth problem is solved by repairing the electricity of the existing system. With this improvement, the process of removing iron balls can be done one by one. The test officer can place several iron balls at once for testing that requires multiple impacts.

The improvement of the control system is illustrated as shown in **Figure 5**. This control system adds a menu for officers to select the test mode. Each test mode refers to the national standards that have been established for different types of glass. The implementation is shown in **Figure 6**.

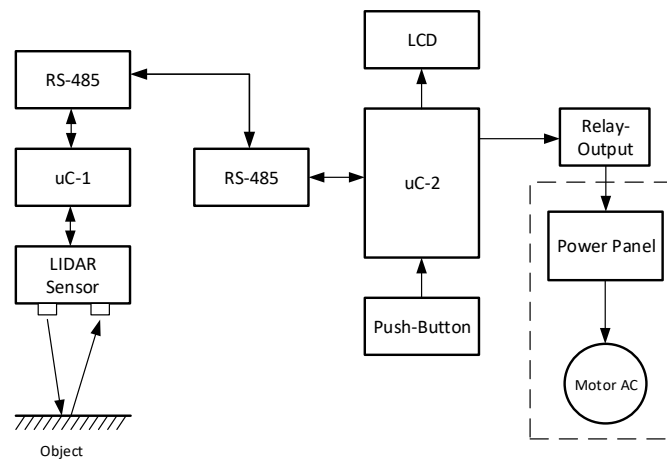


Figure 5. Improved Platform Altitude Control System.



Figure 6. Impact Test Platform Altitude Control System Implementation

The algorithm in the control system of the iron ball launcher platform is given in **Figure 7**. These system updates are then tested to measure the accuracy of each different test. There are six different height settings that are each tested five times. **Table 1** displays test results from all altitude settings. The error was calculated using the following Equation 1.

$$Error = \frac{\bar{H} - H_T}{H_T} * 100\% \quad \text{Eq. 1}$$

Where $\bar{H}$ is the mean of real height measurement and H_T is the target height.

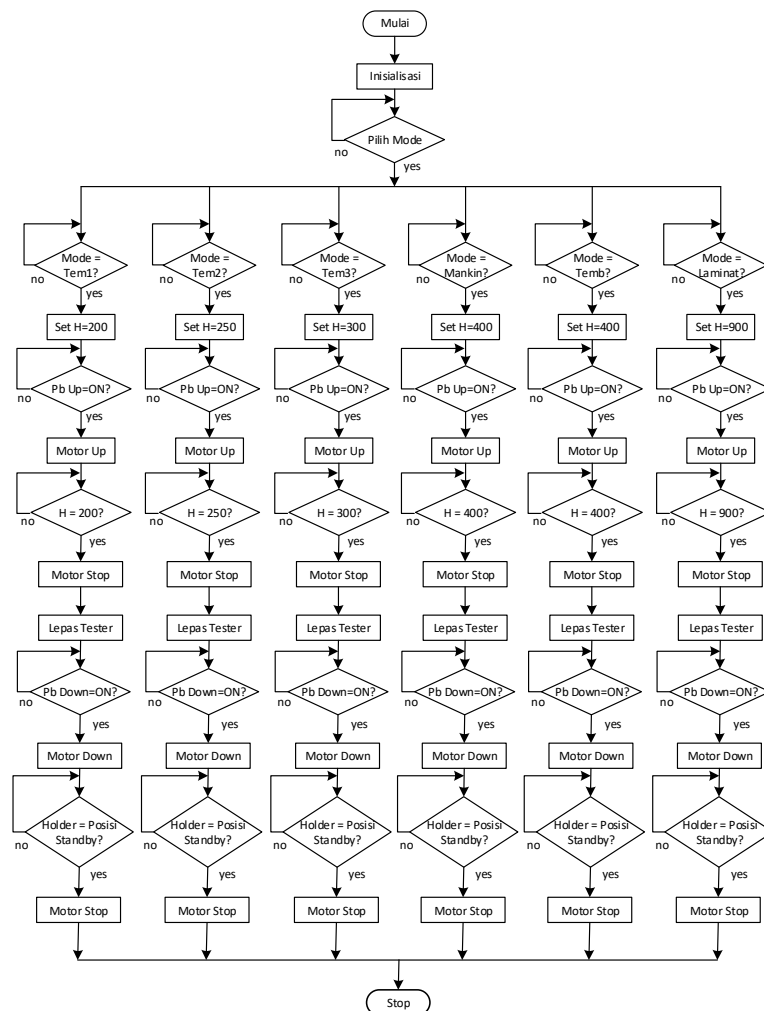


Figure 7. Iron Ball Launcher Platform Algorithm Flowchart

Table 1. Result from Different Settings of Height

No.	Mode	H-Setting (Hs) cm					H-Actual (Ha) cm					Error %
		1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	
1	Tem1	200	200	200	200	200	200	201	202	201	200	0,01
2	Tem2	250	250	250	250	250	251	250	251	250	251	0,01
3	Tem3	300	300	300	300	300	300	301	302	301	300	0,01
4	Mankin	400	400	400	400	400	401	402	401	401	400	0,01
5	Through	400	400	400	400	400	402	401	400	402	401	0,01
6	Laminat	900	900	900	900	900	900	903	901	900	901	0,01

4. Conclusion

Based on the results of the analysis, there are four problems that must be solved in the glass impact test system at BBK. These problems are manual distance measurement, outdated safety systems, momentum movement from chain-based controls, and finally the launch of iron balls that cannot be sequenced.

These four problems can be solved by applying the concept of industry 4.0, namely using communication technology based on digital systems. The system is programmable so that problems in measurement and momentum can be corrected through the program. Implementation has also been carried out and tested where the test results prove that the errors made do not exceed 1%.

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