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DESIGN AND DEVELOPMENT OF AN AUTOMATED IMPACT TESTING SYSTEM WITH INTEGRATED SOFTWARE FOR CHARPY AND IZOD STANDARDS

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ABSTRACT

Impact testing is a crucial mechanical test method used to determine the toughness of materials under sudden loading conditions. Manual impact testers, although effective, face limitations in terms of precision, human dependency, and lack of data automation. This paper presents the development of an automated impact testing system conforming to both Charpy and Izod standards, with a robust graphical software interface. The software supports test setup, test execution, data acquisition, and report generation while managing user security and calibration protocols. The system ensures accurate energy measurement through digitally captured hammer velocity and height, dynamic unit conversion, and automatic statistical calculations. A user-friendly interface enables intuitive control over testing parameters, storage, and analysis. The solution is ideal for material testing laboratories and educational institutions where repeatability, traceability, and compliance with ASTM and ISO standards are critical.

Keywords: Impact Tester, Charpy Test, Izod Test, Software Automation, Energy Measurement, User Interface, Material Testing, Test Report, Serial Communication, ASTM D256, ISO 179.

Introduction

Impact testing is an essential mechanical testing method used to determine a material's toughness by evaluating its ability to absorb energy during a sudden impact. The Charpy and Izod methods are the most widely used standardized approaches for this purpose, with specifications outlined under ASTM D256 and ISO 179. These tests involve striking a notched specimen with a swinging pendulum hammer and measuring the energy absorbed in fracturing the specimen.

Conventional impact testers, although mechanically accurate, often suffer from the following drawbacks in modern quality control or educational labs:

- Manual test configuration and operation
- Error-prone handwritten data logging
- Absence of real-time data visualization
- Lack of centralized storage and test report generation
- No integration with modern computer systems or protocols

To address these limitations, the present project involves the development of a PC-based software application using Visual Basic (VB), designed to interface with a Programmable Logic Controller (PLC)-based impact testing machine. The communication between the software and hardware is established via USB (Universal Serial Bus).

The key goals of the project are as follows:

1. Provide a Graphical User Interface (GUI) for complete test cycle control—setup, execution, and reporting.
2. Interface seamlessly with the PLC to read test data such as release angle, hammer energy, and velocity.
3. Support both Izod and Charpy test modes with unit conversions (J, kg-m, N-m).
4. Enable multi-user access with secure login, admin control, and batch test history.
5. Generate automated reports with statistical analysis, real-time graph plotting, and batch-level summaries.

The result is a modernized digital impact tester system combining the reliability of PLC hardware with the flexibility and ease-of-use of a VB-based GUI, suitable for industrial material testing labs and educational institutes alike.

Literature Review

Impact testing systems have evolved significantly over the decades—from fully mechanical testers to semi-automated systems and, more recently, digitally controlled testers with data acquisition and reporting capabilities. This evolution is driven by increasing demands for precision, traceability, and compliance with international standards such as ASTM D256 (Izod) and ISO 179 (Charpy).

1. Traditional Impact Testers: Earlier systems were purely mechanical. The pendulum was manually released, and the energy absorbed was read from a dial gauge. While reliable for basic testing, such systems lacked automation, result storage, and error checking. They were also susceptible to human error during configuration, data recording, and result interpretation.

2. Microcontroller-Based Automation: Several research efforts have focused on embedding microcontrollers into impact testers. These designs offered some automation by measuring angular displacement and converting it into energy readings. However, most such systems were limited by:

- Fixed displays (no GUI),
- Manual calibration steps,
- Lack of flexible communication interfaces (no PC integration),
- And difficulty in managing user data or batch-wise reports.

3. PLC-Based Industrial Automation: Programmable Logic Controllers (PLCs) have long been used in industrial control systems due to their reliability, modularity, and real-time performance. Their use in material testing is well documented. PLCs offer precise control of hammers, sensors, and safety interlocks, making them ideal for rugged environments.

However, most PLC-based impact testers still lack high-level data processing and user-friendly interfaces unless paired with a dedicated PC-based application.

4. Role of PC-Based Applications in Testing Systems: The integration of Visual Basic (VB)-based PC software with PLC hardware introduces powerful capabilities:

- Customizable GUI for test configuration and monitoring
- Communication over USB, allowing real-time data capture
- Data storage, analysis, and plotting using desktop processing power
- User access control and report generation
- Compatibility with printers and USB drives

Several systems now incorporate PC software to add intelligence to hardware-controlled testers, as seen in tensile testers, compression testers, and vibration analyzers.

5. Gap Identified

While PLCs are widely used in impact testing machinery, literature lacks detailed implementations of a dual-platform solution (PLC + PC GUI) tailored specifically for impact testing with support for Charpy and Izod modes, unit conversions, automated reports, and user management.

This project fills that gap by developing a Visual Basic-based GUI software tightly integrated with a PLC-driven mechanical setup, communicating over USB, and conforming to ASTM and ISO impact testing protocols.

System Design: The automated Impact Tester system is developed using a dual-platform architecture, consisting of:

1. A Programmable Logic Controller (PLC) for hardware-level control and real-time signal processing.
2. A Visual Basic (VB) based PC software that manages the graphical interface, user operations, test logic, and data handling.

This modular division ensures that hardware control and data processing responsibilities are cleanly separated, enabling precise control and user-friendly operability.

1. Hardware Design (PLC System): The hardware system is built around a reliable industrial PLC that interfaces with various components of the mechanical impact tester:

- **Hammer Mechanism:** Controls the release of the hammer with pre-calibrated angular settings based on the selected test (Izod or Charpy).
- **Angle Sensor / Encoder:** Captures the release angle and swing arc to compute energy absorbed.
- **Input/Output Modules:** Monitor safety interlocks, limit switches, and start/stop triggers.
- **Communication Interface:** The PLC is equipped with a **USB-based serial communication** module for data exchange with the PC software.
- **Calibration Settings:** Parameters like hammer length, release height, and velocity (as per ASTM D256 / ISO 179) are predefined and validated.

2. Software Design (VB PC Application)

The PC software developed in **Visual Basic 6.0** (or later) acts as the primary control panel for operators and lab supervisors. The major components are:

A. Graphical User Interface (GUI)

Screens developed include:

- Pre-Login and Login
- Main Menu
- Test Setup (New/Edit/Delete)
- Perform Test
- Test Review and Report
- Admin Panel for User Management
- Calibration and Factory Settings
- Port Configuration and System Info

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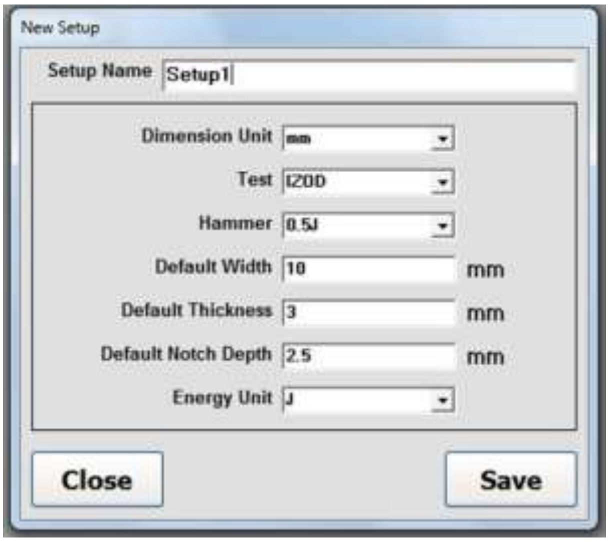
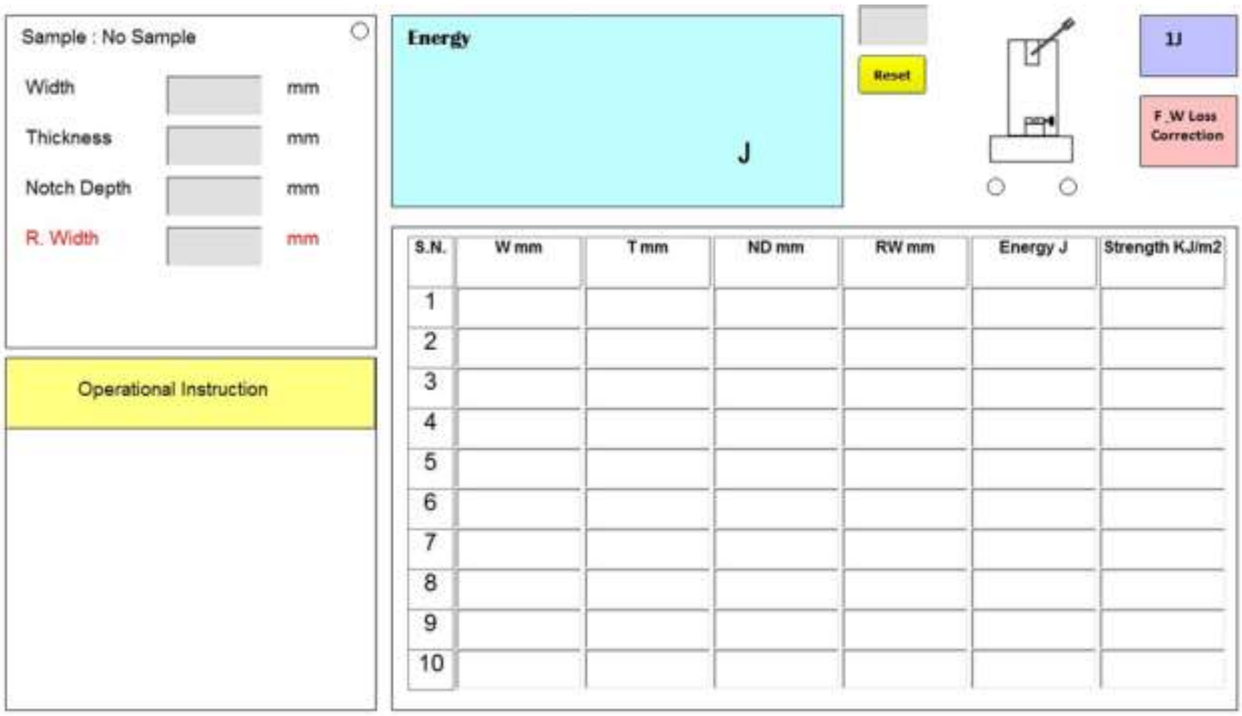




B. Test Modes Supported

- **Izod Mode**
- **Charpy Mode**

Each mode dynamically adjusts the GUI and required parameters such as:

- Hammer size (2J, 2.75J, 4J, 5J, 5.5J)
- Release height
- Energy unit (J, N-m, kg-m)
- Specimen dimensions

C. Software Functional Blocks

- **Database Integration:** All test parameters, user profiles, batch records, and calibration data are stored in a structured database.
- **Unit Conversion & Validation:** The software automatically converts between different measurement units and validates all user inputs against acceptable ranges.
- **USB Communication Module:** Sends commands to PLC and receives real-time data (release angle, energy, test status, etc.)

- **Real-Time Graph Plotting:** Displays energy trends or test results using dynamic charts.
- **Report Generation:** Generates formatted test reports containing:
    - Batch number
    - Hammer type
    - Energy absorbed
    - Test date & time
    - Graph
    - User signature blocks
- **User Management and Security**
    - Admin can add/edit/delete users.
    - Login with validation rules (minimum 8 characters, alphanumeric, special character).
    - Password masking and database authentication.
- **Port Setting Module:** Allows selection of the correct USB COM port for PLC-PC communication.

This system design ensures robust operation under real-world conditions and provides a feature-rich environment for conducting and analyzing impact tests with speed, accuracy, and digital traceability.

Methodology

The development of the automated Impact Testing System followed a structured methodology comprising hardware integration, software development, communication handling, and validation. Each phase was carefully planned to ensure compliance with industrial testing standards (ASTM D256 for Izod and ISO 179 for Charpy), ease of use, and robustness in data handling.

1. Requirements Analysis

- Identified the need for an automated solution to reduce manual operations, avoid recording errors, and support both Izod and Charpy standards.
- Planned for full PC control via a GUI developed in Visual Basic, with PLC-based hardware control.
- Defined key functionalities:
    - Hammer configuration
    - Test execution
    - Data acquisition and processing
    - Secure user login
    - Auto-report generation

2. Software Development Phases

The application development was divided into four major functional modules as follows:

Phase	Module	Description
1	Main + Login Screens	Initial interface and user authentication system
2	Setup Module	Screens for test configuration and parameter entry
3	Test Execution & Graph	Real-time data handling, graph plotting, and control logic
4	Report Generation Module	Final test report formatting, display, print, and export functionality

Each module was developed using Visual Basic forms and integrated step-by-step with the backend database and PLC communication logic.

3. GUI Design & Validation

- Created intuitive screens: Setup, Test, Reports, Security.
- Implemented input validation:
    - Hammer energy levels
    - Specimen dimensions
    - Unit selections (mm, cm, inch, J, N-m, kg-m)
- Real-time error messages and tooltips assist users during entry.

4. PLC Communication (USB Serial)

- The PC application connects with the PLC via a USB-to-Serial interface.
- Commands from PC:
    - Start test
    - Select mode (Charpy/Izod)
    - Read test data
- Data received from PLC:
    - Hammer release angle
    - Impact energy
    - Time stamp

Communication protocol was designed with simple ASCII frames and checksum-based error checking for reliability.

5. Database and Storage

- Each test is stored with full metadata: User ID, Date & Time, Hammer size, Test Mode, Energy, Dimensions, Graph, and Batch ID.
- Admins can review previous batches or generate test reports on demand.

6. Reporting and Graphs

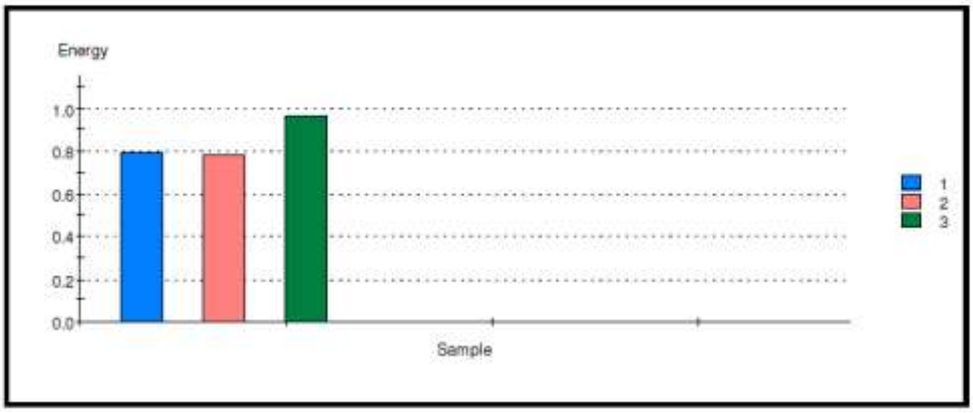
- After each test, a line/bar graph is plotted to show variation or energy absorption.
- Statistical data like Min, Max, Average is calculated automatically.
- Report preview is shown on-screen before export/print.
- Reports are saved in formats compatible with both print and digital backup.

Results:

Sample No.	W (mm)	T (mm)	ND (mm)	RW (mm)	Energy (J)	Strength (KJ/m2)
1	10.000	3.000	2.500	7.500	0.7943	35.3022
2	10.000	3.000	2.500	7.500	0.7776	34.5600
3	10.000	3.000	2.500	7.500	0.9620	42.7556

Statistics:

Result	W (mm)	T (mm)	ND (mm)	RW (mm)	Energy (J)	Strength (KJ/m2)
Maximum	10.000	3.000	2.500	7.500	0.9620	42.7556
Minimum	10.000	3.000	2.500	7.500	0.7776	34.5600
Mean	10.000	3.000	2.500	7.500	0.8446	37.5393
Std. Dev.	0.000	0.000	0.000	0.000	0.0833	3.7009
COV	0.000	0.000	0.000	0.000	9.8587	9.8588



7. Security and Admin Controls

- Admins can add/delete/edit users, assign roles, and access system settings.
- Password rules enforced:
  - Minimum 8 characters
  - At least 1 alphabet, 1 number, 1 special character
- Login activity is logged for traceability.

This structured methodology ensured that the software met its functional, reliability, and usability goals while ensuring compatibility with the existing PLC hardware and testing setup.

Results and Observations

After the successful integration of the Visual Basic-based software with the PLC-controlled hardware, the automated impact testing system was subjected to multiple validation cycles under both Izod and Charpy test configurations. The key parameters evaluated were system accuracy, user interface functionality, data consistency, and report quality.

1. Functional Performance

The following table summarizes the outcomes of key functions tested:

Feature	Observation
Hammer Selection (2J–5.5J)	Worked correctly with mode-based restriction
PLC Communication	Stable USB communication; real-time data sync
Test Execution	Smooth operation in both Charpy and Izod modes
Graph Plotting	Real-time plotting with dynamic scaling
Unit Conversion	Automatic and accurate (J, N-m, kg-m)
Admin/User Management	Role-based access, password enforcement
Report Generation	Accurate with auto-filled statistical fields
Batch Storage	Secure and retrievable from database

2. Sample Test Output

A test was conducted using a 4J hammer in Izod configuration.

Input Parameters:

- Test Type: Izod
- Hammer: 4J
- Specimen Width: 10 mm
- Thickness: 3 mm
- Notch Depth: 2.5 mm

Output:

- Release Angle: 150°
- Energy Absorbed: 1.2 J
- Velocity: Calculated internally using ASTMD256 formula
- Strength: Computed in KJ/m² using formula:

$$\text{Strength} = \frac{\text{Energy}}{\text{Specimen Width} \times \text{Thickness}} \times 1000$$

Graph:
A bar graph was automatically plotted showing the energy absorbed by the specimen. Graphs were saved along with the test report in PDF and image formats.

3. User Feedback

- **Ease of Use:** Users appreciated the icon-based navigation and dynamic test setup.
- **Error Handling:** Input validation prevented accidental entries and test misconfiguration.
- **Security:** Password-protected logins improved accountability and traceability.
- **Reports:** Reports generated were detailed, standardized, and suitable for submission and audits.

4. Comparison with Manual Testing

Parameter	Manual Tester	Developed System
Hammer Release	Manual lever	PLC controlled
Data Capture	Manual observation	Automatic via USB
Graph Generation	External/manual	Integrated, real-time
Report Generation	Manual (MS Word/Excel)	Auto-generated with graph
Data Backup	Not Available	Database + Export to USB
Calibration Handling	Manual only	GUI-based calibration tool

The results confirm that the developed system significantly enhances operational accuracy, user efficiency, and reporting clarity. It replaces multiple manual steps with automation while offering flexibility through PLC hardware and a powerful PC interface.

Discussion

The developed automated Impact Testing System demonstrates a successful integration of industrial-grade PLC hardware with a feature-rich PC-based Visual Basic software, offering a balanced combination of mechanical robustness and digital intelligence. The observations gathered during testing reveal several important outcomes worth discussing in the context of system performance, user experience, industrial utility, and scalability.

1. Improved Accuracy and Repeatability

Traditional impact testers rely on manual triggering and visual reading, which often introduces human error in observing release angle, energy, and interpretation of results. The PLC-driven hammer release and automated reading of angular displacement in the proposed system eliminate such inconsistencies. With predefined hammer settings and unit conversions, the system ensures uniformity across all tests, thereby improving repeatability and traceability.

2. User Interface and Workflow Efficiency

The GUI developed in Visual Basic was designed around the workflow of actual lab operators. By structuring screens such as:

- Setup → Test → Report → Review, users can follow a step-by-step process, reducing confusion and improving test speed.

Features like input validation, tooltips, preloaded parameter values, and graphical buttons made the software intuitive, even for non-technical users. The login-based user control system also introduced accountability by associating test results with specific users.

3. Test Standard Compliance

By aligning parameter settings with ASTM D256 for Izod and ISO 179 for Charpy, including hammer length, release height, and velocity-based energy calculation, the system complies with international standards. The correct conversion formulas for energy units (J, N-m, kg-m) ensure that test results are consistent and globally acceptable.

4. Automation of Reporting and Analysis

One of the most significant improvements over traditional systems is the automatic report generation, which includes:

- Complete test metadata (batch number, user, time, energy values)
- Computed statistical fields (min, max, average, strength)
- Auto-plotted graphs
- User signature fields for documentation

These reports are stored digitally and are printable/exportable, reducing paper dependency and enabling instant sharing via USB or email.

5. System Flexibility and Modularity

The use of a PLC for hardware control provides industrial ruggedness and reliability, while the PC application layer introduces flexibility and ease of modification. This separation allows for:

- Future upgrades in GUI without modifying hardware
- Addition of new test standards or hammer sizes
- Integration with wireless systems or cloud-based storage

6. Limitations and Future Scope

While the system performed successfully, the following enhancements are proposed:

- Addition of real-time monitoring graphs during hammer swing
- Support for networked database to enable access from multiple PCs
- Remote test monitoring via web-based dashboard
- AI-based test recommendation or defect detection in future versions

This discussion shows that the developed system not only meets the core needs of automated impact testing but also sets the foundation for intelligent, scalable, and standards-compliant material testing platforms.

Conclusion

The developed system for automated impact testing represents a significant advancement over conventional manual and semi-automatic testers by combining the precision of **PLC-controlled hardware** with the flexibility and intelligence of **Visual Basic-based PC software**. Designed to support both **Charpy** and **Izod** testing standards, the system successfully automates key aspects of the impact testing process including test setup, execution, data acquisition, unit conversion, graphical analysis, and report generation.

By implementing USB-based serial communication between the PLC and the PC, the system ensures accurate data exchange with minimal latency. The integration of user authentication, batch-wise data storage, calibration tools, and graphical reporting adds practical value for academic, research, and industrial laboratories. The GUI's intuitive layout, validation mechanisms, and statistical calculations minimize the scope of operator error and improve overall test efficiency.

The system meets the core objectives of:

- Standard compliance (ASTM D256 / ISO 179)
- Automated and error-free data handling
- User and security management
- Flexible reporting and record-keeping

It is well-positioned for use in quality control departments and educational institutes where reliable, repeatable, and traceable impact testing is critical. The modular design enables future extensions such as cloud connectivity, remote monitoring, AI-based analytics, and wireless operation.

In conclusion, this project demonstrates how thoughtful integration of industrial hardware with modern software can transform traditional testing systems into smart, user-friendly, and audit-compliant platforms—bridging the gap between mechanical reliability and digital intelligence.

References

[1]. ASTM International, "Standard Test Methods for Determining the Izod and Charpy Impact Resistance of Plastics," ASTM D256.

[2]. International Organization for Standardization (ISO), "Plastics — Determination of Charpy Impact Properties," ISO 179.

[3]. Programmable Logic Controllers – Hardware and Programming, by Max Rabiee, Delmar Cengage Learning.

[4]. Microsoft, "Visual Basic 6.0 Programming Documentation," Microsoft Developer Network (MSDN), [Online].

[5]. Rockwell Automation, "PLC Communication via USB to PC – User Guide," Rockwell Technical Documents, 2019.

[6]. ActiveReports Documentation, "Generating Custom Reports with Graphs and Tables in VB," GrapeCity Developer Solutions, 2020.

[7]. A. K. Sharma, "Automation in Mechanical Testing using PLC-SCADA Architecture," *International Journal of Engineering Research and Technology*, vol. 8, no. 4, 2020.

[8]. J. L. Kolhe and N. Yadav, "USB-Based PLC Communication Interface for Testing and Control Applications," *IJRASET*, vol. 7, Issue 11, 2019.