Design Hybrid Platform Gauge for Railway Infrastructure Testing in IoT-Based Railway Station Emplacements

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Abstract. The technical requirements for minimum rail gauge and platform clearance at station emplacements are essential to support railway operations, given the large number of train accidents caused by rail gauge and platform clearance that do not follow applicable regulatory standards. However, data collection from the measurement of rail gauge and platform clearance still uses manual tools and handwriting, which needs to be improved to save human resources and time. Therefore, optimizing the process of testing the rail gauge and the platform clearance requires equipment that can work automatically to collect data and record measurement results. The IoT-based Hybrid Gauge platform design aims to optimize the measurement of rail gauge and platform clearance at the station emplacement and reduce the need for human resources and time. Testing the gauge of the rail and platform clearance in this study was carried out by utilizing a rotary encoder to detect the dilation and narrowing of the width of the railway track. In addition, the VL53l1X lidar sensor detects the distance and height of the platform clearance on the station emplacement. The Control system of the hybrid platform gauge uses an Arduino Uno microcontroller connected to a web application on a laptop by utilizing the Wemos D1 Mini for sending data from sensor readings. The results of the Platform Gauge Hybrid design showed that this device could operate on a 1067 mm-wide R54 rail with a measurement accuracy rate of 99.29% and a percentage of time efficiency of 85%.

Keywords: Internet Webserver · Rail Gauge · Platform Clearance · Rotary Encoder

1 Introduction

Railway infrastructure consisting of the railroad, train stations, and rail operating facilities is vital to support rail operation activities. One of the standards applied to maintain the safety of rail transportation modes is the Railway Infrastructure Technical Requirements Standard. One of the efforts made by the Directorate General of Railways to ensure the quality of the level of safety of railway transportation infrastructure is to carry out tests, both the first test and periodic testing of railway infrastructure components.

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Fig. 1. Railroad Manual Measurement Tools: (a) Platform Gauge, (b) Meter Gauge

However, based on observations made in the first testing process of railway infrastructure on the Banjar-Kroya lines, the testing of railway infrastructure is still done manually using a meter gauge and platform gauge (Fig. 1) along with test forms and stationery [2–4]. Problems that arise from the use of manual equipment in the testing process are problems of time and energy efficiency [5]. These problems include transferring data from the test form sheet into a Word document after completing the entire testing process. For this reason, it is necessary to improve the testing process by using automated equipment to increase the effectiveness and efficiency of the implementation of railway infrastructure testing. Therefore, this study will describe a hybrid measuring instrument design that can connect with a web application that can be accessed directly and wirelessly on the examiner's laptop to increase the efficiency of the test activities for the rail gauge and the platform clearance at the railway station emplacement.

2 Research Methodology

Following the Regulation of the Minister of Transportation Number 30 of 2011 [1], which regulates that testing of the railway infrastructure, including platform clearance and rail gauge, must be tested for eligibility to support railway operations. The hybrid platform gauge is expected to improve the performance of railway infrastructure testing. This device can measure the railgauge, platform clearance, and mileage simultaneously. In addition, the measurement results obtained from this device will be stored and displayed in real-time on applications integrated with the Hybrid Platform Gauge.

In this case, we can use a personal laptop connected to a measuring instrument to support rail track testing activities and clearance in the field. With the existence of a hybrid platform gauge, it is expected to increase the effectiveness and efficiency of carrying out rail line testing. In addition, using a hybrid gauge platform can reduce the risk of losing test data because it is already stored in the database. By utilizing the lidar sensor, the measurement numbers obtained are more accurate.

2.1 Device Control System Design

This design expects the device to take measurements in conditions moving on railroads to reduce the need for time and energy to test the railway infrastructure. A hybrid gauge platform system connected to a laptop requires the following components:

1. Rotary Encoder

   Rotary encoders generally use optical sensors to produce serial pulses that can interpret motion, position, and direction. Then the angular position of a rotating object shaft can be processed into information in the form of a digital code by the rotary encoder to be passed on by the control circuit [6].
2. Lidar Sensor (VL53l1X)

   The electronic rangefinder is an electronic device that uses laser waves or microwaves to measure distances. The VL53L1X module is a proximity sensor module that uses the time of flight laser method to make distance measurements have a high notarization compared to other proximity sensors, such as ultrasonic sensors [7]. In addition, VL53L1X integrates the leading SPAD lineup (Single Photon Avalanche Diodes) [7].
3. Arduino Uno R3

   Arduino is a microcontroller-based board on the ATmega328. The board has 14 digital input/output pins (of which six pins can use as PWM output), six analogue inputs, 16 MHz crystal oscillators, a USB connection, electric power, an ICSP head, and a reset button. To program the Arduino Uno, we can use the Arduino IDE application [8].
4. Wemos D1 Mini

   Wemos D1 mini ESP8266 is a Wemos D1 mini Wifi-based module development board from the ESP8266 family that can be programmed using Arduino IDE software. One of the advantages of this Wemos D1 mini is that a shield module is available for plug-and-play support [8–11].
5. Database

   The database is a collection of data and descriptions of data that are logically connected and designed to meet the information needs of an organization [12]. By database, the data owned can manage in such a way following specific provisions that can interconnect in its management.

   Web application designing is created by utilizing *Bootstrap* as a template from the Interface and *CodeIgniter platform* to set the functionality of each component on the web application. The developed web application will connect with the local MySql database to store and process data from the web application [13]. In integrating the electronic components used for measurement detection, an Arduino Uno microcontroller is used, which can be programmed using the Arduino IDE application [14]. Arduino acts as a control for reading sensor measurement data and sending it to Wemos D1 Mini to be sent to the web application. Then the system can display the measurement result data in real-time through the laptop to the device. The Block diagram of the hybrid gauge platform system can be seen in Fig. 2.

The wiring design to integrate the components needed to run the platform gauge hybrid system uses ISIS Proteus 7.0. Wemos D1 mini is connected to the Arduino Uno microcontroller by connecting the RX pin on the Wemos D1 Mini to the TX pin on the Arduino Uno, and the TX pin on the Wemos D1 Mini is connected to the RX pin on the Arduino

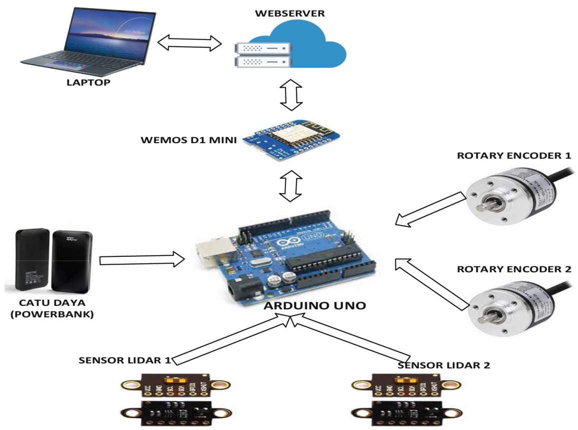


Fig. 2. Block Diagram

Uno. This function sends the data obtained into the web application through communication between the Arduino Uno and the Wemos D1 Mini wifi module with the help of the internet network.

2.2 Calibration Measurement Device

Device calibration settings are carried out on sensors that function to read rail gauge and clearance on the station platform, namely the Vl53l1X lidar sensor and Rotary Encoder, in the following manner:

a. Rotary Encoder Calibration

The rotary Rotary encoder measurements were carried out by calculating the circumference of the surface in contact with the head Rail. The surface in touch with the rail head is the wheel's surface, which is integrated with the rotary encoder. The result of the circumference of the wheel surface in contact with the rail head is then accumulated with a constant and the number of ticks according to the technical specifications of the rotary encoder used. To find the circumference of the surface in contact with the rail head, the equation for the circumference of a circle can be used as follows:

$$K = 2.\pi.r \tag{1}$$

b. VL53L1X Lidar Sensor Calibration

A calibration process is required to improve the accuracy and precision of this lidar sensor's distance readings. Calibration lidar sensors take several distance samples and then compare the measurement results from the designed measuring instrument with a standardized tool. For example, to find out the average Vl53l1X sensor measurement results will be obtained with the following equation:

$$\overline{\mathrm{x}} = \frac{\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{xi\ fi}}{\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{fi}} \tag{2}$$

By comparing the measurements between the Vl53l1X sensor measurements and a standard meter measuring instrument, a standard deviation of the distance reading error on the sensor for measurements with a common measuring instrument will be obtained, and the percentage accuracy of the Vl53l1X sensor measurements. The standard deviation formula for the measure can be seen in the following equation:

$$\Delta x = \sqrt{\frac{\sum_{i=1}^{n} (\overline{x} - xi)^2}{n(n-1)}} \tag{3}$$

Meanwhile, the formula for the precision of the Vl53l1X sensor measurement can be calculated using the following equation:

$$\text{Precision} = \left(1 - \left|\frac{H - \overline{x}}{H}\right|\right) \times 100\% \tag{4}$$

By obtaining the standard deviation value of the Vl53l1X sensor measurement for measurements with standard measuring instruments and the average value of the Vl53l1X sensor measurement, then we can determine the percentage of accuracy of the Vl53l1X sensor reading system that has been designed using the following equation:

$$\text{Accuracy} = \left(1 - \frac{\Delta x}{\overline{x}}\right) \times 100\% \tag{5}$$

2.3 Algorithm System Device

The process of using the Hybrid Gauge platform to test the railroad at the station emplacement must follow the previously designed procedures. The steps for using the hybrid gauge platform can be seen in Fig. 3. Before operating the Platform Gauge Hybrid device, the tester must ensure that the System can connect the hardware and software via the local internet network. That aims to turn on and start the process of railway infrastructure testing on the field. So that the results of measurements taken by Platform Gauge Hybrid can be displayed on the tester's laptop monitor screen.

The operating system process using the Platform Gauge Hybrid must ensure the operating system can operate well. Therefore, the Operation of the Platform Gauge Hybrid must test the entire device system, both application or software testing, and measurement testing. Software testing is done using the Black Box Test method by testing the smallest unit of an application function. The measurement testing is done by determining the percentage error value from the measurement results displayed on the application. By comparing the measurement results of the distance sensor with the results of standard measurements using a meter, it will produce a measurement difference, and the percentage error can be known using the general percentage formula as follows:

$$Error\% = \frac{x - y}{y} \times 100\% \tag{6}$$

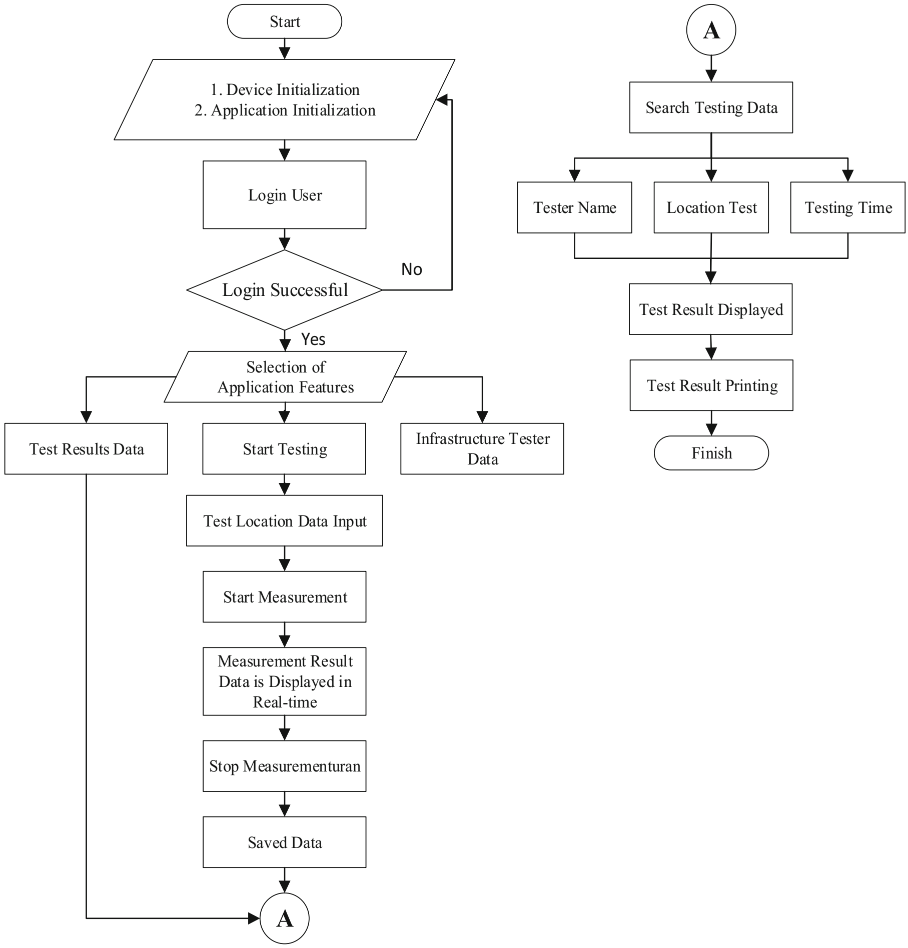
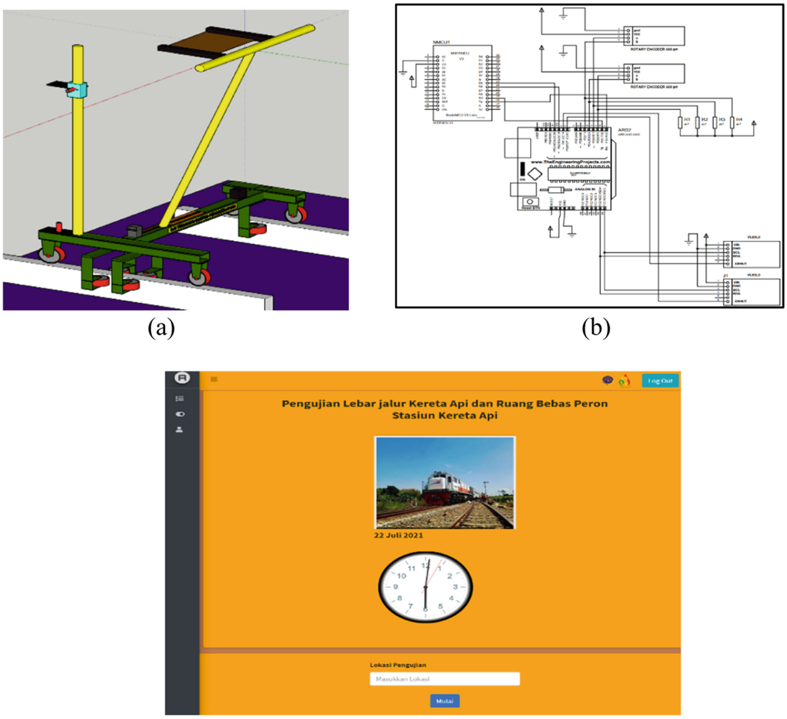


Fig. 3. Flowchart Operation Process

3 Results and Discussion

3.1 Hardware, Web Application and Wiring Design

The device is designed to take measurements in moving conditions on the clearance of the platform and the width of the railway line in the station emplacement. Therefore, this device requires a tool frame design that can work properly and run on railroads according to the type of railroad in the field. The framework design of the tool can be seen in Fig. 4. The results of the design of the Arduino Uno and Wemos D1 Mini wiring systems can be seen in Fig. 4. The process of connecting components with the components used is to connect the pins contained in each element with the pins on the Arduino Uno Microcontroller. The main page of the web application, is a section that includes the details of the test location before the test of the width of the rail and the clearance of the platform. In addition, on the main page, there are several widgets,



(a) (b) (c)

Fig. 4. (a) Hybrid Platform Gauge Design using SketchUp, (b) Schematic Wiring Design, (c) Main Page Web App View

namely the test date and time, the logout button, a label to fill in the test location, and a button to start the test.

3.2 Device Function Test

Testing the Hybrid Platform Gauge System involves software and measurement testing with this device. On the first page, there is a login page where the username and password must first be registered in the database by the admin. Then the main page of the application test serves to enter the details of the location, time, and button to start testing. Next, the test monitoring page is used to monitor the measurement results, and the test result data page displays the measurement result data. The last page is the examiner's identity page, which displays the examiner's identity. Software testing on web applications will be tested using the Black Box Test method in the login page function, the measurement Start and Stop Buttons, and the search function and filtering of the test result data. This testing ensures that the web application design can run as expected. Based on the specifications of the wheel diameter used and the specifications of the rotary encoder used, the maximum speed that can be used in the Hybrid Platform Gauge system can be known by the following equation:

Table 1. Web Application Test Results

No.	Testing	Result
1	Login/Logout Function	Appropriate
2	Search function and Filtering of Test Result Data	Appropriate
3	Measurement Start and Stop Button Functions	Appropriate
4	Tester's Data Edit Function	Appropriate

$$\begin{aligned} V &= \left(\frac{S}{t}\right) \\ &= \left(\frac{wheel\ \ circumference(m) \times n}{\mathrm{t}}\right) \\ &= \left(\frac{0,\,1884 \times 600}{60\,\mathrm{s}}\right) \\ &= \left(\frac{0,\,1884 \times 600}{60\,\mathrm{s}}\right) \end{aligned} \tag{7}$$

The functional testing of each component constituting the web application aims to ensure that accessing and transmitting data from the process of testing platform clearance and the rail gauge runs well. From the data in Table 1, the overall function testing of the constituent components of the web application can work according to a predetermined design.

The measurement results using manual instruments are used as a reference or comparison of the measurements that will be carried out using the Hybrid Platform Gauge. To make it easier for the author to sample measurement data, the twenty-five data taken are measurements every 25 cm on the same path used as a test location for railgauge measurements and platform clearance using the Hybrid Platform Gauge. Measurements using the Hybrid Platform Gauge device in millimeters and the error values can be seen in Table 2. Based on the measurement data, the average error value is 0.67%, with an accuracy percentage of 99.33%. The comparison graph of the measurement results using a hybrid gauge platform and manual measurements can be seen in Fig. 5.

Based on interviews conducted with a train infrastructure tester from the Railway Testing Center, data were obtained for implementing platform clearance testing and rail gauge using manual measuring instruments at the station emplacement within 1 km, which took 1 h. Meanwhile, the time required to test using the *Hybrid Platform Gauge* with a maximum speed of 1 km is obtained through the derivation of the speed formula as in the following equation:

$$t = \left(\frac{S}{V}\right)$$

$$t = \left(\frac{1000\,\mathrm{m}}{1.89\,\mathrm{m/s}}\right)$$

Table 2. Hybrid Platform Gauge Measurement Test Results

No. Meter to-	Rotary Encoder		Sensor Lidar		Comparison of error ratio with manual measurements			
	Mileage	Rail Gauge	Platform Clearance Distance	Platform Clearance Height	Mileage	Rail Gauge	Platform Clearance Distance	Platform Clearance Height
1	256	1067	1606.5	413	2.40%	0.00%	0.34%	0.96%
2	509	1067	1606.5	419	1.80%	0.09%	0.28%	0.96%
3	773	1069	1608.5	412	3.07%	0.19%	0.09%	0.00%
4	1031	1068	1610	414	3.10%	0.09%	0.00%	0.48%
5	1282	1067	1607.5	420	2.56%	0.09%	0.09%	0.72%
6	1539	1067	1607.5	418	2.60%	0.09%	0.28%	0.00%
7	1795	1068	1611	416	2.57%	0.09%	0.12%	0.73%
8	2048	1068	1608	417	2.40%	0.00%	0.06%	0.97%
9	2298	1067	1610.5	415	2.13%	0.00%	0.28%	0.72%
10	2551	1066	1609	416	2.04%	0.09%	0.25%	0.24%
11	2805	1068	1612	416	2.00%	0.09%	0.00%	0.24%
12	3055	1068	1608	417	1.83%	0.19%	0.12%	0.24%
13	3310	1066	1610	416	1.85%	0.00%	0.31%	0.48%
14	3568	1067	1608.5	420	1.94%	0.00%	0.28%	0.72%
15	3820	1068	1608	420	1.87%	0.09%	0.00%	0.96%
16	4074	1067	1603.5	417	1.85%	0.09%	0.34%	0.24%
17	4326	1066	1606	413	1.79%	0.09%	0.37%	0.96%
18	4578	1067	1608.5	415	1.73%	0.09%	0.09%	0.00%
19	4831	1067	1606.5	417	1.71%	0.00%	0.16%	0.00%
20	5088	1068	1609	417	1.76%	0.09%	0.31%	0.00%
21	5338	1066	1610	416	1.68%	0.00%	0.12%	0.48%
22	5592	1067	1609.5	418	1.67%	0.09%	0.03%	0.48%
23	5847	1067	1608.5	415	1.69%	0.00%	0.22%	0.48%
24	6100	1066	1606	415	1.67%	0.00%	0.12%	0.00%
25	6357	1066	1609	414	1.71%	0.09%	0.12%	0.00%
AVERAGE PERCENTAGE OF ERROR					**2.06%**	**0.07%**	**0.18%**	**0.44%**

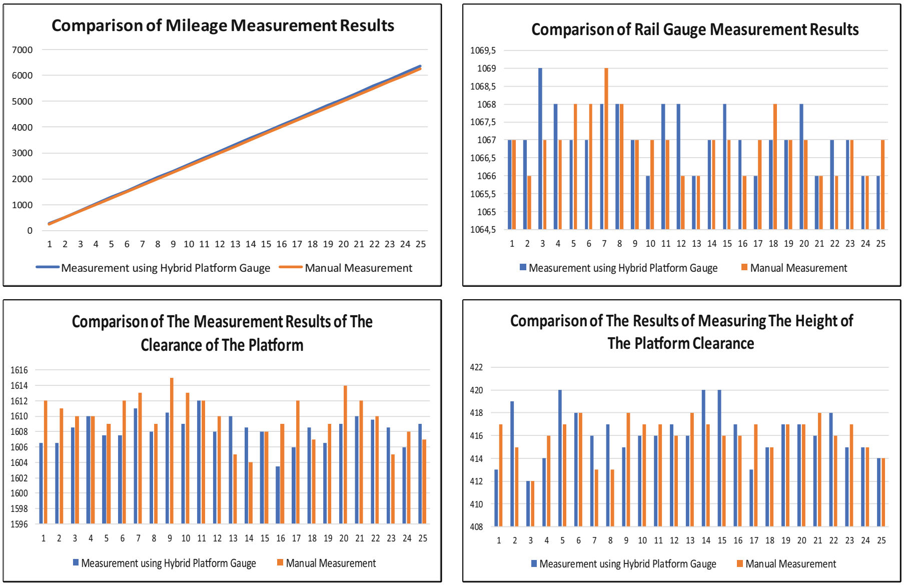


Fig. 5. Hybrid Platform Gauge Measurement Comparison Graph with Manual Measurements

$$= 529, 10\,\mathrm{s}$$

$$= 8 - \text{minutes and } 49 - \text{seconds} \approx 0.15 - \text{hours}$$

$$\approx 0.15 - \text{hours}$$

From the calculation of speed and time, it was found that the difference in time between the two objects was found. The time required to test the platform clearance and track width at the railway station emplacement is 1 km long, 8 min 49 s, or 0.15 h with a maximum speed of 1.89 m/s. Testing of the platform clearance and rail gauge at the station emplacement using a hybrid gauge platform that has been designed as efficient with a faster time of 51 min and 11 s, compared to a manual measuring instrument. The time efficiency value of using *the Platform Gauge Hybrid* on platform clearance testing and line width in the station emplacement can be seen in the following equation formula:

$$\begin{aligned} \textit{Efisiensi} &= 100\% - \left(\frac{Ty}{Tx} \times 100\%\right) \\ &= 100\% - \left(\frac{0.15\,\mathrm{h}}{1\,\mathrm{h}} \times 100\%\right) \\ &= 100\% - (15\%) \\ &= 85\% \end{aligned} \tag{8}$$

4 Conclusion

Based on the data from the research that has been carried out, the author can draw the following conclusions:

1. The design of the web application program is made using a bootstrap template with the help of a Code igniter framework while monitoring measurements, namely by using an Arduino Uno microcontroller integrated with the Wemos D1 mini, which functions as a medium for sending data from the tool to the web.
2. The way measurements work using the Platform Gauge Hybrid is by using two rotary encoders to determine mileage and the widening and narrowing of railroads by integrating with linear-CNC. As for measuring platform clearance, namely by utilizing two VL53l1x lidar sensors.
3. Measurements using the Hybrid Gauge Platform designed on rails with a lane width of 1067 mm have been able to work well because they have an accuracy rate for measuring mileage of 97.94%, for rail gauge measurements of 99.93%, for the width of the platform clearance measurements of 99.82% and height of the platform clearance measurements of 99.56%.
4. The maximum speed that the Platform Gauge Hybrid can reach in the platform clearance and rail gauge testing process is 1.89 m/s and has a time efficiency of 85%.

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