# Innovation in the Development of Rail Elevation Inspection Tools Using a Combination of Binoculars Precisions Optic and Laser Sight

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**Abstract.** The maintenance of railway infrastructure is crucial to ensure operational reliability and safety, especially for railway tracks. This research focuses on designing an elevation inspection tool using a combination of precision optics telescope and laser sight. The tool's design considers strength, user-friendliness, and accuracy, utilizing aluminum series 6061 material and a magnetic clamp system for efficiency. The telescope and laser are employed to facilitate measurements. Test results indicate comparable precision to existing tools. The tool is expected to enhance the efficiency and effectiveness of railway track maintenance, ensuring stability and safety for train traffic. Its implementation aims to optimize maintenance practices and improve railway safety overall

**Keywords:** Railway Track Maintenance, Track Elevation Inspection Tool, Laser Sight, Precisions Optic

## 1 Introduction

According to Minister of Transportation (PM) Regulation Number 32 of 2011, infrastructure maintenance is carried out to maintain the reliability of the infrastructure so that it remains operational [1][2][3]. All infrastructure used and operated must carry out maintenance such as on routes, stations and other facilities to maintain the function of the infrastructure so that it is always in good condition and safe to pass through, which can prevent accidents arising from poorly maintained infrastructure. On railways maintenance is required on the rail lift to stabilize the rail elevation due to the dynamic loads generated by the train[4]. Uneven rails can occur due to a decrease in rail elevation, so before carrying out maintenance on the rails it is necessary to check to find out the height to which the rails must be raised. This is very important to prevent danger to rail traffic. If the rail elevation is not adjusted properly, the train will experience shaking when passing over it. This can disturb the comfort of train users and prevent trains from moving at the expected speed. In fact, the worst thing that can happen is a train going off the track, which is known as a derailment. Lifting work is carried out if the difference between the toritic height value and the height value is >7mm, then the railroad must be repaired immediately. If the difference in the calculated skilu value (at two points three meters apart) is greater than the supposed skilu limit, the railroad must be repaired immediately[6] [7].


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It is very important to use a rail level checker in order to level the rail elevation. Examination using this tool must be carried out before force maintenance is carried out. If force maintenance and elevation checks can be performed simultaneously, maintenance time can be saved. Therefore, a tool is needed that can facilitate the maintenance of forces on the railroad. The measuring instrument commonly used in force and electrical maintenance is a force ruler with nylon thread, and binoculars with reading tanks are also used[8].

This force's binocular and ruler tools have shortcomings in terms of setting the tool which requires a center point to be used, the time to determine the center point affects working time during window time and, the function of the tool is less effective because it cannot be used during night work and during measurements[9,10]. Using other tools such as gauges, meters, and it takes a lot of workers just for measurements[11]. For effective measurements, a simple tool is needed but has maximum function in its use and in the design of the tool, a magnet is used as a replacement for the clamp holder with the aim of making it easier to install on the rail, the scope part uses a larger diameter with the aim of being able to reach further distances and be clearer. measuring tank reading, there is also the addition of a laser pointer as an alternative for measuring at night and also has a function as a replacement for thread for electrical measuring instruments. Thus it is increasingly clear that it is necessary to modify and design good, effective, strong, and accurate force measuring instruments. So that maintenance in the field can work optimally. Based on this background, the author decided to make a spirit pass tool as an update to existing conventional tools to optimize and make the railroad maintenance process more effective.

## 2 Research Method

Manufacture of force rulers and electricity with this laser waterpass by analyzing data from observations of the design process can be carried out. Design using autoCAD software. In tool testing using ANOVA, measurement data obtained from the tool being tested is compared with measurement data from the existing tool. The aim is to find out whether there is a significant difference between the measurement results of the tool being tested and the existing tool. If during testing there are obstacles, a re-design is carried out to overcome the obstacles so that they can match the planned performance. To determine the accuracy of the tool, a comparison of the tool measurement results was carried out with PT KAI's elevation checking tool. From the comparison, it can be determined the advantages and disadvantages of a rail elevation checker with a combination of precision optical binoculars and a laser sight

# 3 Result and Analysis

## 3.1 Tool making process

### 3.1.1 Tool Design

The design is carried out using Autocad software on a laptop or computer as the initial planning. Design how the tool works by placing the tool at a high point to seek obedience or increase in elevation [5]

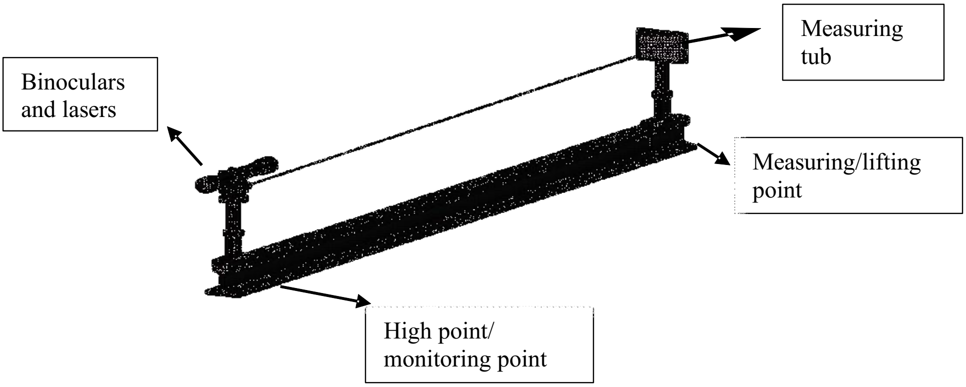


**FIGURE 1.** How the Tool Works

To determine the tool to be made to meet the efficiency to be achieved, several design options for this rail elevation checker were made. According to Rams, (2018) good design principles for determining design criteria for making rail elevation checkers are easy, strong, fast, and accurate [2]

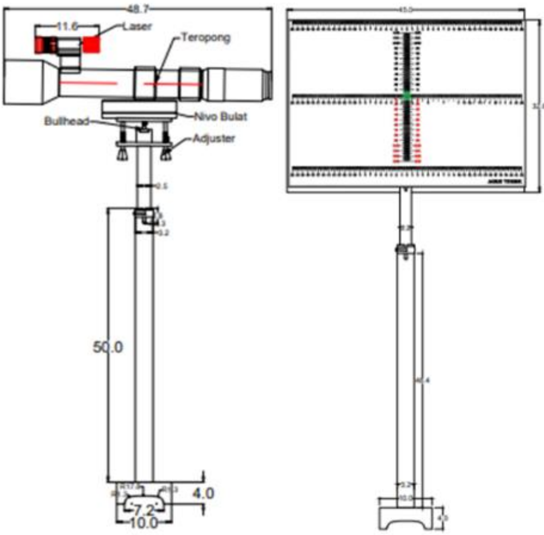


**FIGURE 2.** Shooter and Measuring Tank Design

3.1.2 Tool Components and Materials

The components and materials of the spirit level laser use the following specifications (1) Aluminum 6061 80mm thick, (2) Aluminum pipe OD 30 mm, (3) Aluminum pipe OD 25 mm, (4) Precision Optics Binoculars, (5) Laser sights, (6) Magnets, (7) Water level (bubble split) (8) Measuring tub, and (9) adjusters

3.1.3 Tools Fabrication

Fabrication stages (1) Making r54 rail prints on cardboard by punching method, (2) Formation of clamp from aluminum block, (3) Making a magnetic place. Making coakan magnets is adjusted to the diameter of the magnet, which is 20 mm, (4) Making a place and installing water level (nivo), (5) Making adapters and supports with drilling machines, (6) Formation of the support pipe according to the initial design, (7) Making threads on aluminum pipes, (8) Making adjusters on pipes and clamps, (9) Ensure that it is in accordance with the dimensions on the design, (10) Making measuring tanks by utilizing UV printing technology services so that manufacturing can produce clear and neat numbers, (11) Shape into a tool.

**FIGURE 3.** Finlas Tool shape

### 3.1.4 Tool Calibration

Calibration is carried out on the measuring tank to ensure that the scale used is appropriate. Calibration by measuring the scale on the measuring tank using a caliper. The first calibration is calibration to determine the straightness of the laser by ensuring that the direction of the laser beam is truly straight by measuring the distance from the rail header to the laser beam on the shooter and placing a measuring tank 2-3 meters away and measuring the height of the beam from the rail header to the fall of the beam. Next, calibration is carried out to determine the position of the tool above the rail head and place the zero point on the measuring tank. Because the shape of the tool's legs has been shaped to match the profile of the rail head, it can be ensured that the position of the tool is at the midpoint of the rail head. The next calibration is the tilt of the binoculars and laser. By paying attention to the position of the bubble at the water level in the middle so that the position of the tool and binoculars are perpendicular. Accuracy calibration for lasers and binoculars uses the same method. By making binoculars in zero condition (0).

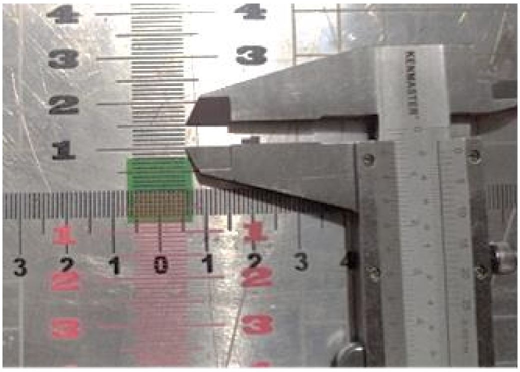

**FIGURE 4.** Gauge Calibration

### 3.1.5 Tool Testing

The step to determine the performance of the tool is to carry out testing. Testing was carried out for 3 days on the Panjang-Mojokerto route km 56+550 – 56+367. Testing and data collection were carried out according to the standards used by the railroad resort accompanied by the head of the Mojokerto resort. Measurement results from a spirit level binoculars. The difference between the measurement results, the measurement results with the laser and the measurement distance. To find an analysis of the data above, the authors used the single factor ANOVA method that was provided to Ms. Excel.

$$MAPE = \Sigma\ (|A - F|) X \frac{100}{n}$$

A (value)
F (Measured Value)
n (Lots of Data)

The measurement results are interpreted using tables:

**TABLE 1.** Interpretation of Mape Results

| Range MAPE | Interpretation |
|---|---|
| <10% | Excellent forecasting model ability |
| 10-20% | Good forecasting model ability |
| 20-50% | Worthy forecasting model ability |
| >50% | Poor forecasting model ability |

## 3.2 Results and Analysis

The results of the design of the rail elevation checker with a laser waterpass consist of 2 parts, namely the laser scope and measuring cup. It is different from the cross binoculars belonging to the railroad resort, which only have binoculars and a measuring cup. The working position is in use with a sitting position looking straight ahead


**FIGURE 5.** Tool Work Illustration

The workings of this laser waterpass are by looking at the unit that is visible on the measuring cup. This unit is seen when the line on the telescope is in a perpendicular position and the reticle is in the measuring cup. Whereas for use at night using a laser that is fired at a measuring cylinder to get a height value. From the finished product, the following specifications are obtained:

**TABLE 1** Waterpass Laser Specifications

| Part | Spesification |
|---|---|
| Material | Full Aluminum |
| Attachment System | Magnetic Clamp |
| Shooter Component | Telescopic with 40mm Lens Dimension and Laser with a Maximum Distance of 500m |
| Tool Dimensions | Height 60cm Adjustable can be adjusted to Examiner Posture Up to 120cm |
| Tool Segment | Consists of 2 Parts: Binoculars and Measuring Tub |
| Balancing Indicator | Equipped with a Waterpass on Each Part of the Tool to Ensure the Tool is in Flat Condition when Used |
| Types of Binoculars | Precition Optics |
| Overall Weight | 4.5 Kg Whitout Box |

The step to ensure that the tool can work well is to test the tool's performance by comparing the average results of measurements, the average setting time and the accuracy of the tool. To determine the error using the mape method, get the following sample:

**TABLE 2** MAPECalculation Results

| Old Tools | New Tool | % Error | Category |
|---|---|---|---|
| -1 | -1 | 0 | Excellent |
| -2 | -1 | 25 | Good |
| -2 | -2 | 0 | Excellent |
| -3 | -3 | 0 | Excellent |
| 2 | 1 | 25 | Good |

From the calculation results found no bad category results by getting very good and good results. It can be interpreted that the new tool has a good measurement error rate. To analyze the results of testing the tool is done using ANOVA. From the first test data by collecting data at 62 points using new and existing tools, the results are:

F = 0,042744
Fcrit = 4,723028

Provision
F>Fcrit = Ho rejected,
F<Fcrit = Ho accepted
Ho = the average elevation result of the laser waterpass inspection with binoculars is the same,
H1 = average elevation results of laser waterpass inspection with different cross binoculars.

From the results of the analysis, if F>Fcrit = Ho is rejected, it can be concluded that the two tools have different speeds in the process of using the tool. And the spirit level laser has a smaller setting time.

From the third test data, by taking data at 9 distances, measurements at each distance were repeated 30 times, the results were obtained:

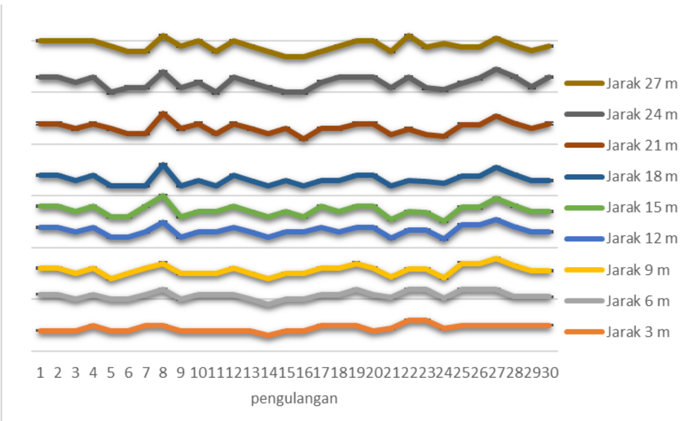


**FIGURE 6.** Repetition Results Graph

From the graph above it is known that increases and decreases in value occur in adjacent repetitions, so it can be interpreted that this tool has stability and regularity in the results, so there is no random value in the examination results. From the results of the third test were analyzed again using the standard deviation calculation method. Standard deviation is a concept in statistics that is used to measure how far the data is spread from the average value. The lower the standard deviation value, the closer the data is to the average value. Meanwhile, the higher the standard deviation value, the greater the distance between the data and the average value. The standard deviation is also known as the standard deviation and can be represented by the sigma symbol (σ) for the population or the symbol s for the sample. This concept is very important in data analysis because it helps in measuring the degree of variability

**TABLE 3.** Standard Deviation

| No. | Distance | Lots of Data | Averages | Standard Deviation |
|---|---|---|---|---|
| 1 | 3 m | 30 | 4.5246 | 0.669972 |
| 2 | 6 m | 30 | 6.3121 | 0.547605 |
| 3 | 9 m | 30 | 4.8333 | 0.530067 |
| 4 | 12 m | 30 | 7.6667 | 0.379049 |
| 5 | 15 m | 30 | 3.9201 | 0.406901 |
| 6 | 18 m | 30 | 5.9300 | 0.527289 |
| 7 | 21 m | 30 | 10.0333 | 0.490132 |
| 8 | 24 m | 30 | 8.7333 | 0.691491 |
| 9 | 27 m | 30 | 7.1333 | 0.819307 |

In this case, if the standard deviation < average, it can be concluded that the data has a high level of consistency and tends to be homogeneous. (Fisher, R.A, 1920). The graph of the average and standard deviation at each distance can be shown as follows:

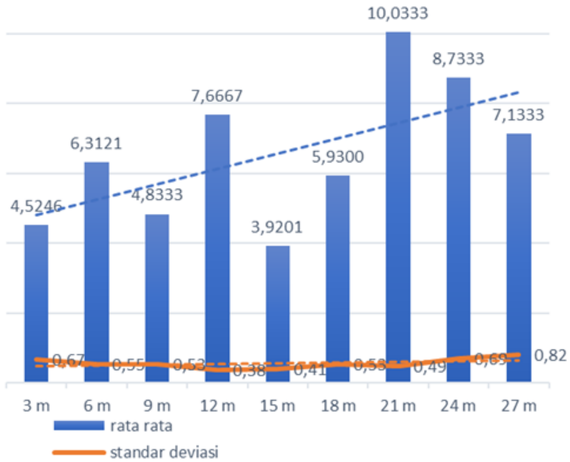


**FIGURE 7.** Average Test Results

The linear line that slopes upward shows that the standard deviation at each point is different. It is known that the tool can be used in optimal conditions at a distance of + 30 meters and is feasible to be used as an inspection tool with reference to PM No. 32 of 2011 states that elevation checks are carried out at a distance of 15-25 meters

## 4 Conclusion

Based on the design criteria, namely strong, easy to use, fast in operation, and accurate, efforts were made to fulfill these criteria on the shooting equipment. This tool uses full aluminum series 6061 material which is light and weather resistant. The magnetic clamp system without a threaded lever speeds up installation. A telescope with a focusing range of 100 meters is used to maintain the accuracy of the tool. Lasers with proven military grade specifications were selected. On the measuring tank, the design uses different colors in the numbers to make reading easier. Unit numbers are made per millimeter to avoid inaccurate estimation methods. From the results of testing the rail elevation checker tool with a laser waterpass, an analysis was carried out with PT.KAI's tool, the result was that the waterpass laser had almost the same accuracy (not significant) and it can be said that this tool fulfills as a rail elevation checking tool as an auxiliary and optional tool that can be used in Force maintenance.

Operators need to understand how optical and laser precision rail elevation checking tools work, including how to operate them, the necessary settings and routine maintenance. Operators must be trained in the use of this equipment, including calibration, operation, handling common problems, and interpretation of the resulting data. The tool has the advantage that it can be used during the day or night and is resistant to fog and dew, the tool is designed to be as simple as possible in its use so that it can be used by all operators, the time required is shorter so that it increases worker effectiveness, the dimensions and load of the tool are light and easy to mobilize. by operators. The cost of making this tool is IDR. 3,500,000.

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