Prototype of portable measurement instrument for turnout motor power in railway system

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Abstract. A prototype of rail turnout motor measurement device was designed based on motor torque inspection, using a load cell sensor. A rail turnout is a branched railroad construction to control the railroad track that controlled by turnout motor, therefore it is one of important railways elements for guiding and directing the train to not derailment or collide with another train. The device was made in order to check the reliability of turnout machine in railway systems. In Indonesia, currently the inspection of turnout machine was done manually and still not so efficient in term of the process. Here, we built a portable system device consisted of load sensor, processed with a microcontroller and the data were recorded and displayed in a Liquid Crystal Display (LCD). The device was tested directly to a turnout machine on the railroad at Kiara Condong Station, Bandung, Indonesia. The measured results showed that the device working properly and the average pulling strength of turnout machine at the station was 256.6 ± 2.88 kg.

1. Introduction
Railway transport is one dependable public transportation [1,2], because it is not so affected by weather conditions, free from traffic jam, and travelling time is also well predicted. In order to provide decent public transport service [3], the railway safety system becomes an important factor to ensure that the journey of train goes well. All safety support devices related to train journey have to be in proper condition to be used, so the train travels could be carried out without a hitch. Failure in a safety device/instrument could interrupted the train schedule and furthermore causes time and financial losses, both for the company as well as passengers [4,5]. Conclusively, it is very important to ensure the reliability of devices involved in efficient railway system operation, to reduce safety concern.

A rail turnout/switch/point is a branched railroad construction to control the railroad track, from one rail track to another. It is one of crucial railways elements [6,7] for guiding and directing the train journey from one track line to another one, as for interlocking system [8,9]. Interlocking system controls and determines all train safety and journey, in railway systems. Turnout is necessary and crucial element in railway systems: sometimes two or more trains run on the same track at the same time. Trains must be temporarily diverted to another track, particularly when the trains will stop at the station or be transferred to another destination track. Generally, the turnout is moved by turnout machine and usually it is remotely controlled [10,11]. The turnout machine has to be in always proper condition, especially its motor torque. Poorly maintained point machine could lead to failure when switching tracks and
potentially causes derailment [12,13] and or collision [14,15] among trains. In Indonesia, a rail turnout machine condition is still checked manually. The officer in charge will take the turnout at the railroad track periodically and move it to the workshop for checking, inspecting and maintenance. Then the inspection results are recorded manually in a report book. The process is not so convenient, since the motor has large dimensions and heavy if moved. The officer also has to replace the turnout machine in the railroad with another one, if there is an inspection schedule. At present, there is no portable measuring device to check the strength of the turnout motor for the switch, particularly in Indonesia railroad. Therefore, it is important to have such kind of device, since it determines the turnout motor strength, particularly when pulling/pushing the turnout. The device could provide direct information and condition of the turnout machine.

In this research work, a prototype design of the turnout motor measurement device was built based on motor torque inspection through the load cell sensor. The device was designed to become portable, therefore it is easy to be used in different locations. The device system itself is consisted of a load cell sensor, interface module, microcontroller and the recorded data is shown on a Liquid Crystal Display (LCD) monitor. As mentioned earlier, in Indonesia, all turnout machine inspections were done in manual way. Having this kind of portable measurement device gives several benefits such as: 1) measurement results could be stored automatically, therefore the inspection history could be used for predictive maintenance of turnout machine in the future, 2) it is a portable device, therefore the officers just only bring this device to the railroad that want to be inspected and measure the turnout power directly in the field.

2. Methodology
The design system built in here is consisted of a load cell sensor to read the weight scale, as the output of turnout motor. The data were firstly amplified before processed in a microcontroller. After processing, the data was stored as well as displayed on an LCD, as described in Figure 1. The summary of the components used in this work is shown in Table 1.

![Figure 1. Electronic system design.](image)

| Component      | Type                | Function                  |
|----------------|---------------------|---------------------------|
| Load Sensor    | S-Beam Load Cell YZC-516 | Measure weight            |
| Microcontroller| Arduino Uno         | Controlling electronic system |
| Interface Module| HX711              | Amplifier                 |
| LCD            | 16x2 LCD Module     | Display                   |

For calibration of load sensor, it was done by comparing the ADC output value from the sensor when load from a balance (Type Salter 219) was added to the sensor. Different type of loads was given to the sensor, with an interval weight of 140-360 kg and increment 10 kg. The obtained data were subjected for regression process, to match the sensor reading and actual weight scale.

After the sensor was calibrated, the device was tested directly to a turnout machine with type 20122B/T84M located on the railroad at Kiara Condong Station, Bandung City, West Java, Indonesia. The railroad here belongs to PT. Kereta Api Indonesia (KAI), Persero. The turnout machine was
inspected by switching the turnout on the railroad (from straight to turn position and vice versa) for 5 (five) times each and the data were recorded. Illustration of data collection is displayed in Figure 2 (a). Since the physical appearance of sensor and turnout is not fit, a bracket was used to adjust the sensor position to the movable turnout, as designed in Figure 2 (b).

![Figure 2. (a) Illustration of turnout motor power measurement and (b) bracket for fitting the sensor with railroad.](image-url)

3. Results and discussion

3.1. Calibration

Before measurements, the load sensor was firstly calibrated by pressing the sensor using a balance, Salter 19 type, as illustrated in Figure 3 (a). Loads were added to the sensor that gradually increases, in the range of 140-360 kg with increment 10 kg. The load added was recorded against the value of the ADC output from the load cell. Several data points from calibration process was subjected for linear regression, for analyzing the tendency of sensor reading against actual load added. Figure 3 (b) shows the calibration curve of the load sensor for this research work, as a function of load added against ADC output. The load added and ADC output value correlation has a linear tendency, with the gradient of the curve is 36.8214. The calibration process shows a valid value, since the linear regression result shows that the value of $R^2 = 0.99387$, which is very close to 1. Calibration results indicated that the sensor had good reading and comparable with actual weight for balance.
3.2. Measurement

The photograph of the built device during measurement is displayed in Figure 4. It can be seen that the device is portable and no additional instrument is required, therefore it will not interfere the railroad track or train journey. To fit the physical casing of sensor and railroad, a bracket was required, as illustrated in Figure 2 (b) previously. From here, the turnout machine was assessed by recording the mass of movable turnout during switching.

Table 2 shows the measurement data of the device at turnout machine located at Kiara Condong Station, Bandung City, Indonesia. From five times data taking (the turnout was moved repeatedly), the average measurement obtained was $256.6 \pm 2.88$ kg for point that moved from straight to turn position and $250 \pm 5.61$ kg. The repeating data indicated that the device had good precision reading and proper to be used. From the turnout itself, value of ~$250$ kg is categorized in good condition. According to the type of
turnout machine model, this type of turnout machine has sprung coupling that should move the load (turnout) translational with mass between 224.34-326.31 kg.

Table 2. Measurement of turnout machine at Kiara Condong Station, Bandung City, Indonesia.

| Position of point       | Mass pushed/pulled by the point machine (kg) |
|-------------------------|---------------------------------------------|
| Straight to turn position | 255, 253, 259, 260, 256                   |
| Average Reading         | 256.6 ± 2.88 kg                             |
| Turn to Straight position| 240, 256, 252, 253                        |
| Average Reading         | 250 ± 5.61 kg                              |

4. Conclusion and future work
Here we reported how making portable measurement instrument for turnout machine inspection in the railway system. The system utilized load sensor that processed with a microcontroller and the measured data is displayed on an LCD and saved into a database. Measurement results showed the device was reliable to be used in real condition of turnout machine. The device can be said is ready for duplication and could be placed on every turnout exist in Indonesia railroad. If the built system is developed again embedded with communication system, such using Internet of Things (IoT), therefore real-time and online monitoring system could be conducted in one center station only. If development of this implementation can be done in the future, the inspection process of turnout could be easier and failure system could be reduced.

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