

ABSTRAK

Rel kereta api memiliki risiko deformasi akibat fluktuasi suhu lingkungan dan tegangan mekanis yang dapat mengancam keselamatan perjalanan. Penelitian ini merancang sistem *monitoring* berbasis *Internet of Things* (IoT) menggunakan mikrokontroler ESP32 sebagai unit akuisisi data utama. Sistem ini mengintegrasikan sensor DHT22 untuk suhu dan kelembapan udara, sensor NTC 10k *glass bead* untuk suhu material rel, serta *strain gauge* BF350 untuk mendeteksi regangan mekanis. Pengujian dilakukan di KM 8 Sadang, Purwakarta, dengan merekam 497 data secara *real-time* melalui protokol HTTP POST ke *database cloud*. Hasil pengamatan menunjukkan suhu material rel mencapai titik tertinggi 47,80°C yang berkorelasi dengan peningkatan deformasi hingga 80,72. Algoritma *Random Forest Regressor* diimplementasikan untuk memprediksi deformasi rel berdasarkan parameter lingkungan. Model ini menunjukkan performa tinggi dengan koefisien determinasi (R^2) sebesar 0,9002 dan *Root Mean Square Error* (RMSE) sebesar 2,2112. Pada pengujian lapangan, sistem mampu memprediksi deformasi dengan stabilitas tinggi pada rentang 6,36 mm hingga 7,19 mm. Implementasi ini membuktikan bahwa integrasi sensor fisik dan algoritma pembelajaran mesin dapat berfungsi sebagai *soft sensor* yang andal untuk pemantauan integritas struktural rel.

Kata Kunci: ESP32, *Strain Gauge*, *Random Forest Regressor*, Deformasi Rel, IoT, Akuisisi Data.



ABSTRACT

Railway tracks are susceptible to deformation caused by ambient temperature fluctuations and mechanical stress, which can jeopardize transportation safety. This study develops an Internet of Things (IoT)-based monitoring system utilizing the ESP32 microcontroller as the primary data acquisition unit. The system integrates a DHT22 sensor for air temperature and humidity, an NTC 10k glass bead sensor for rail material temperature, and a BF350 strain gauge to detect mechanical strain. Field testing was conducted at KM 8 Sadang, Purwakarta, recording 497 data points in real-time via the HTTP POST protocol to a cloud database. Experimental results indicate that the rail material temperature reached a peak of 47.80°C, correlating with an increase in deformation up to 80.72. A Random Forest Regressor algorithm was implemented to predict rail deformation based on environmental parameters. The model demonstrated high performance, achieving a coefficient of determination (R^2) of 0.9002 and a Root Mean Square Error (RMSE) of 2.2112. During field trials, the system consistently predicted deformation within the range of 6.36 mm to 7.19 mm with high stability. This implementation demonstrates that the integration of physical sensors and machine learning algorithms can function as a reliable soft sensor for monitoring rail structural integrity.

Keywords: ESP32, Strain Gauge, Random Forest Regressor, Rail Deformation, IoT, Data Acquisition.

