

ABSTRACT

Track geometry irregularities, particularly alignment and profile irregularities, can affect railway safety and operational performance by altering wheel-rail interactions and generating distinct vehicle vibration responses. This study aims to analyze vibration characteristics caused by alignment and profile irregularities and classify them using a One-Dimensional Convolutional Neural Network (1D-CNN). Vibration data were obtained from multibody dynamic simulations in Universal Mechanism under normal, alignment, and profile track conditions at speeds ranging from 50 to 90 km/h. The vibration data were processed through signal cleaning, sliding-window segmentation, simulation-based labeling, standardization, and partial balancing before model training. Root Mean Square (RMS) analysis was subsequently employed to evaluate the vibration characteristics of each class. The results show that alignment irregularities predominantly generate lateral vibrations, whereas profile irregularities produce dominant vertical vibrations. The proposed 1D-CNN model achieved 94% accuracy, precision, recall, and F1-score, with a Matthews Correlation Coefficient (MCC) of 90%. These findings demonstrate that vehicle vibration responses can be effectively utilized to classify track geometry irregularities and support indirect railway track condition monitoring.

Keywords: *Track geometry irregularity, Alignment irregularity, Profile irregularity, 1D-CNN, Machine learning, Multibody dynamics.*

INTISARI

Ketidakteraturan geometri rel berupa *alignment* dan *profile* dapat memengaruhi keselamatan serta kinerja operasional kereta api melalui perubahan interaksi roda-rel yang menghasilkan respons getaran kendaraan. Penelitian ini bertujuan untuk menganalisis karakteristik getaran akibat ketidakteraturan *alignment* dan *profile* rel serta mengklasifikasikannya menggunakan model *One-Dimensional Convolutional Neural Network* (1D-CNN). Data diperoleh dari simulasi *multibody dynamics* menggunakan perangkat lunak Universal Mechanism pada kondisi lintasan normal, *alignment irregularity*, dan *profile irregularity* dengan variasi kecepatan 50-90 km/jam. Data getaran diproses melalui tahap *signal cleaning*, segmentasi *sliding window*, pelabelan berdasarkan kondisi simulasi, standarisasi, dan *partial balancing*. Selanjutnya, analisis *Root Mean Square* (RMS) digunakan untuk mengevaluasi karakteristik getaran pada masing-masing kelas. Hasil penelitian menunjukkan bahwa *alignment irregularity* menghasilkan dominasi getaran lateral, sedangkan *profile irregularity* menghasilkan dominasi getaran vertikal. Model 1D-CNN yang dikembangkan menghasilkan nilai *accuracy*, *precision*, *recall*, dan *F1-score* sebesar 94%, serta nilai *Matthews Correlation Coefficient* (MCC) sebesar 90%. Hasil tersebut menunjukkan bahwa respons getaran kendaraan dapat digunakan secara efektif untuk mengklasifikasikan ketidakteraturan geometri rel dan mendukung pemantauan kondisi lintasan secara tidak langsung.

Kata kunci: ketidakteraturan geometri rel, *alignment irregularity*, *profile irregularity*, 1D-CNN, *machine learning*, *multibody dynamics*.