Abstract ID 516

A SPEED-DEPENDENT MODEL-BASED APPROACH TO THE MONITORING OF TRACK IRREGULARITY

Stefano Alfi, Matteo Santelia, Ivano La Paglia, Egidio Di Gialleonardo, Alan Facchinetti

Politecnico di Milano

stefano.alfi@polimi.it, matteo.santelia@polimi.it, ivano.lapaglia@polimi.it, egidio.digialleonardo@polimi.it, alan.facchinetti@polimi.it

Keywords: Track geometry, Model-based condition monitoring, Unknown input observer

Summary: To ensure the safety and efficiency of railway networks, track geometry must be periodically inspected and maintained. Deviations from the nominal track geometry can lead to increased dynamic loads, passenger discomfort, and, in extreme cases, safety risks. For high-speed railway lines, inspections are typically carried out using dedicated track recording vehicles, which are specialized trains equipped with inertial and optical sensors. However, these vehicles entail significant costs in terms of production, maintenance, and in-line operation, restricting their use mainly to high-speed and highly trafficked lines. In recent years, alternative strategies have been explored to enable more frequent and cost-effective monitoring. One promising approach involves using instrumented in-service vehicles, which allows for continuous data collection during normal operations. This strategy significantly reduces costs and extends monitoring capabilities to conventional railway and metro networks, where dedicated track inspection vehicles are seldom used. This paper presents a model-based condition monitoring method for track geometry assessment, leveraging an unknown input observer (UIO). The proposed approach utilizes accelerometer measurements from an in-service vehicle to infer track irregularities. The vehicle is modelled as a dynamic system, where rail irregularities act as unknown inputs, and acceleration signals serve as measurable outputs. By ensuring that the sensor configuration satisfies input observability conditions, the UIO is capable of reconstructing not only the overall level of track irregularities but also their spatial distribution along the railway line with high accuracy. This feature provides two key advantages for infrastructure managers. First, it enables continuous monitoring of track geometry variations over time, allowing for early detection of track degradation and progressive wear. Second, it provides precise localization of irregularities exceeding threshold limits, ensuring that maintenance interventions are targeted only where necessary, optimizing costs and operational efficiency. A key challenge in track monitoring using in-service vehicles is the variability of operating conditions, particularly speed fluctuations along the line. The proposed UIO method explicitly accounts for speed variations, making it especially suitable for metro systems, where trains typically operate under variable-speed conditions, with frequent accelerations and decelerations between stations. The feasibility of the proposed method is assessed through numerical experiments. A nonlinear multi-body dynamic model of a metro vehicle is used to simulate its response to different track irregularity profiles under variable-speed conditions. Acceleration data collected from these simulations serve as input for the UIO-based reconstruction process. Different case studies are analysed, considering variations in both speed profiles and track irregularity severity. The results demonstrate the method's effectiveness in accurately reconstructing the track irregularity profile and its frequency content. The findings confirm the suitability of the proposed approach for real-world applications, providing a robust and cost-efficient solution for track condition monitoring using instrumented in-service vehicles.