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Background

Inefficient management of rail surface defects can increase maintenance costs, safety hazards, service disruptions, and catastrophic failures like rail breaks. To achieve adequate management, having effective technology capable of timely detecting and frequently monitoring rail defects is of utmost importance. The aim is early detection of defects to maintain safety levels and prevent the re-appearance due to residual damages.

Figure 71-1 The installed ABA system

Various measurement technologies, such as visual inspections, geometry profile measurements, and other measurement techniques, have been used for the detection of rail defects. While these methods provide insights, they often lack the capability for early-stage defect detection. Thus, most of these technologies are suitable for reactive maintenance since they detect defects when they reach a certain severity level. Axle box acceleration (ABA) technology provides a solution capable of frequent monitoring, mounted on trains in operation without dedicated measurement vehicles (see figure 71-1). Its basic principle is to use a train as a moving load that excites the infrastructure and to detect defects by evaluating the time-frequency characteristics of the dynamic response measured by accelerometers installed on axle boxes of the train. ABA systems have shown promise in detecting defects in the early stages. However, its widespread application and need for robustness require further validation and development. This work presents the results of detecting and monitoring rail surface defects using ABA technology.

Increased knowledge and implementable results

Figure 71-2 The measured locations

Extensive measurement and validation campaigns were conducted along the Iron Ore line between Sweden and Norway (see figure 71-2). This line is mostly single-track with passenger–freight mixed traffic and heavy axle load (up to 31 t). The measurement train ran two round trips along the line for approximately 400 km and analysed ABA data almost in real-time for rail defect detection. No prior information about the location of defects and the type and location of railway assets was required. This campaign used the ABA measurements from the vertical and longitudinal directions to detect rail defects, including squats. The high sampling frequency of 25.6 kHz was also considered to capture the characteristics of small defects in their early development.

Photo: Siwarak Unsiwilai

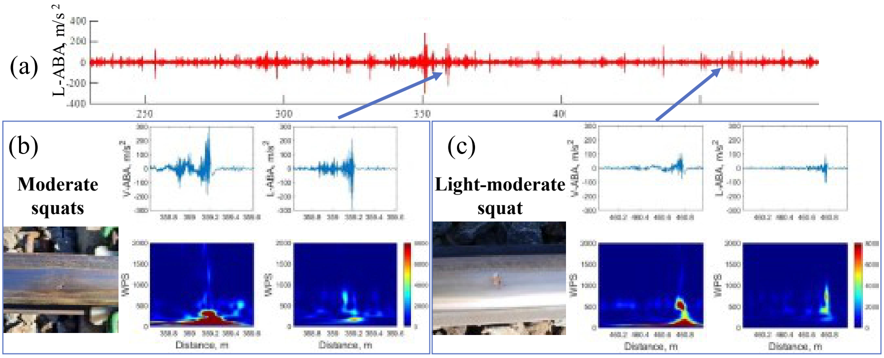

Figure 71-3 Example of the ABA measurements of a rail portion from Location 1

By analysing data acquired from the accelerometers in vertical and longitudinal directions, the locations of rail defects are determined based on the variations of the obtained ABA energy. Figure 71-3 illustrates an example of the ABA measurements in which relatively high energy is observed in the signal. In accordance with the Dutch definition, squats refer to localised rail head deformation, initially without visible cracks. Squats are classified into three classes based on their visual size – light, moderate, and severe. The localised deformation causes an impact, progressing into moderate and severe squats, characterised by a V or U-shape during their moderate and severe stages. Illustratively, figure 71-3(b) demonstrates the ABA energy at a location corresponding to a moderate squat, while figure 71-3(c) depicts that of a light-moderate squat. These rail defects, including squats, are detected using an outlier detection approach (detecting energy variations beyond local average values). According to our validated sections, 100% of rail defects were detected using time-frequency analysis and an outlier detection approach. This shows the capability of ABA technology for the detection of rail defects. The methodology also allows for identifying priority locations such as defective welds, joints, transition zones, etc. Its use for prescriptive maintenance recommendations is being explored in the framework of the IAM4RAIL project.

After the initial ABA measurement, subsequent measurements of defects and track components update their conditions, allowing for assessing their growth rate. These measurements reveal early defects and help evaluate maintenance effectiveness, e.g., determining the required grinding depth for specific defect severity.

Implementation and open questions

The effectiveness of ABA technology for the detection and monitoring of rail surface defects will lead to integrating ABA technology into existing railway track information systems, enabling continuous monitoring of the ABA energy at critical locations such as welds, S&Cs, insulated joints, transition zones, bridges, etc. Further research and development include extracting and integrating information from diverse data types related to railway assets and defects to synergise with the physical understanding of the ABA signals. Then, the integrated information can enhance the effectiveness and interpretability of continuous monitoring, revealing new insights into defect progression, maintenance requirements, and the overall condition of the railway infrastructure.

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