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Expert Commentary A

TRENDS IN VIBRATION-BASED STRUCTURAL HEALTH MONITORING OF RAILWAY SLEEPERS

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Today vibration-based structural health monitoring (SHM) has been widely used in many applications, i.e. mechanical, civil, or aerospace engineering. Over last decades, SHM has been investigated for uses in those applications as an alternative tool to the costly visual inspections. Most of the SMH applications make effective use of experimental modal analysis and finite element model updating whereas this approach consumes reasonable cost for instrumentation and device (generally only a few accelerometers installed on the structure). In railway communities however, SHM technologies have not been widely adopted as the rail track engineers lack efficient tools and instrumentation to process the SHM for enormous numbers of railway sleepers along the rail tracks. Even though the new innovations for vibration based SHM, which can provide capabilities of measuring new types of data quantities, increased computational power, data rate transfers and data storage, faster data mining, and artificial intelligence for data processing (e.g. wireless and embedded sensors, fibre optical sensors, new dynamic strain gauges, etc.), have been discovered for some years, it is found that the adoption of SHM in railway tracks, especially for railway sleepers, is still very limited.

With the aging of railway tracks and their structural components as well as the wide-spread extensions of rail networks, there is the tremendous demand for SHM technology for railway engineering applications. It is evident by the recent formation of research effort within the framework of the Australian Cooperative Research Centre for Railway Engineering and Technologies (Rail-CRC) to develop non-destructive testing (NDT) tools for

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the condition evaluation and monitoring of railway tracks and their components such as rails, rail pads, fastening systems, track sleepers, and ballast. The ultimate goal is to develop a decision-making tool for track optimal maintenance program. The developments of technological advances for real-time monitoring railway structures using very large networks of sensors also allow track owners to manage the risk involved in track operations.

In rail tracks, rolling stocks usually ride over the rails to transport passengers, goods, etc. The time dependent burden of vehicle and transported mass will transfer to axle, to wheel, and then to track structures. The dynamic effects often excite the railway track components with increased magnitudes at specific frequencies associated with such components. It is found that the railway sleepers deteriorate greatly due to dynamic loads at their resonant frequencies. Cracked sleepers require their replacements as soon as possible, according to the current design concept – permissible stress principle. Therefore, it is imperative to investigate and monitor the structural health condition of railway concrete sleepers.

By nature, the railway sleepers to be monitored are subject to changing environmental conditions and extreme dynamic loading. As a result, important issues such as damage formations, ballast support conditions, creep and shrinkage, and structural performance of sleepers must be considered in the development of SHM tools. Overall, the future trends in SHM include the novelties in three categories: sensors, information and acquisition systems, computational software and methodologies. However, recent developments mainly focus on the sensing technology and modern techniques. The current uses of ultrasonic, radar, infrared, and other wavelet methods are fairly limited in case of sleepers with complex shape and topology because the wave echoes contain a lot of noises due to a number of negative effects such as complex shape and topology, ballast shoulder, chaos and fouling, the reflective effects of internal cracks, wooden fibre directions, reinforcing tendons, fasteners, rusts, corrosions, and so on. These effects also discourage the SHM tool development of machine vision whereas modern image analysis techniques are employed. At present, the vibration-based SHM is the most suitable technique for railway sleepers. In particular, the development of a wide variety of sensors is very important for the selection of various uses in different rail track conditions.

Future investigations would therefore focus on the new technology, which non-destructively monitors the major cracks and structural condition of sleepers using the vibration signals or if possible the filtered ultrasonic/radar echoes. Due to a limitation in space, the non-destructive testing system should be integrated or embedded into the existing or new track systems to form a 'smart track' or 'smart sleeper', which would provide the decision support system to the track managers in order to plan the track renewal programs and schedule the effective logistics of train operations. However, the inclusion of sensors should not undermine the track or sleeper capacity. The other options are either to develop new materials as the damage detector (e.g. embedded nanotubes, etc) or to invent the non-contact vibration measurement systems that could be installed on a track maintenance car (e.g. U-DOPPLER, Magnetic arena, etc). Development of the SHM applications for damage detection in railtrack systems and the track components using the in-depth understanding of dynamical sensitivity and stochastic analysis is still important. With the insight into railway track and sleeper dynamics, the advanced prediction and neural networks model for structural condition identification, damage detection, and health monitoring of railway tracks and their components (especially railway sleepers) are becoming a reality in the near future.