Monitoring of Rail Corrugation Growth on Sharp Curves For Track Maintenance Prioritisation

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This paper presents the utilisation of dynamic wheel/rail interaction to monitor rail corrugation growth already detected on sharp curved tracks, in order to prioritise track maintenance. In general, a railway network generally spans over a large distance, so the structural health monitoring of such a rail infrastructure system is one of the grand challenges in rail industry practice. Especially in an underground or subway system, the facilities, resources, and time period permitted for critical infrastructure inspection and maintenance is considerably limited. As a result, the utilisation and application of any inspection train vehicle has been more demanding than ever. A rail corrugation defect is the periodic, undulated or wave-like vertical alignment of rail surface. Corrugations are typically caused by uneven wears due to the variations of wheel-rail contact stresses. The wavelength and severity of rail corrugations is dependent on track structure, track geometry, traction system, rail vehicle behaviours, and wheel-rail interaction. The rail corrugations are the source of rapid track degradation, poor ride comfort, and nuisance noise. Often, such rail irregularities are initially observed and detected by train drivers and engine ride inspectors. To enable predictive maintenance, a set of rail surface data of a very sharp curve was chosen for demonstration of rail corrugation monitoring by integrating numerical train(track simulations, axle box acceleration data obtained from the calibrated track inspection vehicle "AK Car", and spectral data analytics.

1. INTRODUCTION

Social and economic growth of a city, region or country is inevitably underpinned by rail mass transit. To stimulate sustainable productivity, an urban rail infrastructure is often built either underground or on the surface, surrounded by agglomerate buildings and public communities. Its network generally spans over a large distance. Ongoing operation and maintenance of rail infrastructure systems are critical to public safety, in addition to the routine management of business risks and reliability. With a significant demand from the public to cater faster and more frequent train services (evidenced by the 24/7 railways such as in London, Berlin, Sao Paolo, and many more to come), structural health monitoring of such rail infrastructure systems is one of the grand challenges in practice. Especially in underground train or subway systems, track engineers commonly envisage the facts that the tunnel facilities, resources, and time windows permitted for railway staff to carry out the critical infrastructure inspection and maintenance is, indeed, extremely limited. On the other hand, any tiny period of train-free duration (e.g. 3 hours in Tokyo; 1–2 hours in Hong Kong; or down to 5 minutes in London) in a late night rather discourages on-track activities by the railway staff. This is due to the difficulties and the deficiency of time and access to facilities to carry out any meaningful inspection and maintenance tasks. As a result, the utilisation and application of an inspection train vehicle has been more demanding than ever.1,12,17

Rail corrugation is an irregularity on rail running surface, inducing large dynamic loads and vibrations onto adjacent railway track components as well as rolling stocks. Such a defect is a periodic, undulated or wave-like vertical alignment of the rail surface. The rail corrugations are typically caused by uneven wears, due to the variations of wheel-rail contact stresses. The wavelength and severity of corrugations is dependent on track structure, track geometry, traction system, rail vehicle behaviours, and wheel-rail interaction. The rail corrugations are the source of rapid track degradation, poor ride comfort, excessive vibration, and noticeably nuisance noise. Often such irregularities can be observed on the low rail of small-radius curves. A large number of research studies have been devoted into the fundamental causes and mitigation techniques.6,21,29,30 The effect of rail corrugation wavelengths on noise generations has been the main focus in most studies. It is noted that \( v = f \lambda \) (\( v \) is the train speed, \( f \) is the frequency, and \( \lambda \) is the wavelength). “Contact patch filter” has been found to be a mechanism that attenuates very high frequency effects above 2 kHz. Table 1 shows the frequency ranges associated with railway noises due to rail corrugations. To meet appropriate requirements of rail authority, maintenance and control of rail roughness at various wavelengths are generally carried out by rail grinding and lubrication methods, depending on various factors such as geometry, location, gradient, environments, etc.5,7,14,29 In Australia, an urban rail network suffers from rail corrugations on the low rail in curves. Such defects often regenerate secondary ground-borne vibrations in surrounding environments, such as nearby buildings and structures. In addition to noise issues, the defects incur costly track and train maintenance because the excessive vibrations from wheel/rail interaction undermine structural integrity of those railway assets.21,22 It is important to note that the rail corrugations could also be a source causing other types of rail defects, e.g. rail squats, shelling, etc.3,15,18

On this ground, monitoring and control of rail corrugations is mandatorily required in practice.19,31,32 It is, therefore, very important to develop an alternative monitoring methodology that could be practically applied to special railway tracks with restrictions of safe access and facilities.

The inspection or patrol train vehicle is generally equipped with sensors (i.e. accelerometers, gyroscope, ground-penetrating radar, laser profiling, etc.) and high-speed cameras to