A fresh approach to monitoring wagon wheel health

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Flats on wagon wheelsets continue to pose a derailment risk to railways around the world. Technology company Trilogical believes its novel approach to monitoring vibration could offer more reliable insights into wheelset condition.

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Wheel flats on freight wagons represent a significant concern for the rail industry due to the damage they can inflict on both rolling stock and track infrastructure. A wheel flat develops when a section of a wheel's tread becomes flattened, often caused by wheel slide during braking. This defect results in high impact forces each time the flat contacts the rail, accelerating wear and increasing the risk of derailment.

To mitigate such risks, regulatory bodies across the world have implemented strict guidelines. In the USA, the Code of Federal Regulations (49 CFR § 229.75) defines a defective wheel as one with a flat spot of 2·5 in (63·5 mm) or more, or two adjoining flat spots of 50·8 mm or more. Wagons with such defects are prohibited from operation.

While the European Union Agency for Railways and the International Union of Railways do not specify exact flat size limits, they provide comprehensive guidelines for wheel maintenance and manufacturing to prevent such defects. Nevertheless, wheel flats continue to pose a risk to rail freight operations, and they have been cited as a primary factor in a number of accidents over recent years.

Wheel flats implicated in derailments

Examples of such incidents include a derailment in August 2020 of an oil train at Llangennech near Swansea in the UK. According to railway safety inspectorate RAIB, the derailment was caused by a wheel flat that developed after a brake malfunction led one axle to lock and slide for several kilometres. This meant that the wheels were unable to safely negotiate Morlais Junction, near Llangennech, damaging the pointwork and causing the third wagon to become derailed. The following wagons derailed on the damaged track.

Some of the derailed tank wagons were ruptured in the accident, and the spilling fuel ignited. A 230 mm wheel flat was subsequently identified on the affected wagon wheelset, which had developed as a result of defective brake components. The losses and environmental damage caused by the oil spill and fire in an area of protected natural habitat were estimated at US$75m.

Just over two years later, in October 2022, a severe wheel flat on a cement wagon led to the derailment of five bogie tank cars at Petteril Bridge Junction near Carlisle. This wheel flat developed due to poor adhesion conditions, causing the wheel to stop rotating.

In the USA, meanwhile, the February 2023 derailment of 30 wagons in a Union Pacific coal train at Gothenburg, Nebraska was attributed to the effect of 'high-impact wheels'. This refers to a defective wheel that is applying undue force to the track or a track component; many US railroads use Wheel Impact Load Detector devices to measure the impact on the track of passing wagons.

In the case of this incident, a Federal Railroad Administration report found that one of the 30 freight cars that derailed had a WILD measurement of 578 kN when it passed over the track joint bar that was subsequently found to have broken; the recommended WILD threshold for freight wheel impact is 400 kN. During its investigation in Nebraska, FRA identified eight other freight cars in the derailed train with high-impact wheels.

Detection and monitoring limitations

It is clear from this recent history that the risks posed by wheel defects are not going away, and may indeed rise on railways where freight traffic is also growing. However, mitigating the risks of wheel flats is still a challenge: traditional detection systems, such as trackside impact detectors and bogie-mounted sensors, are limited in scope and functionality.

Photo: RAIB

The scene of the freight train derailment near Carlisle, northwest England, in October 2022.

Trackside detectors are fixed in specific locations and can only measure impact as a railcar passes a particular point, providing snapshots rather than continuous insight into wheel condition. They are incapable of alerting train crews in real time, thus limiting their value for immediate safety interventions. Bogie-mounted sensors, while more proximate to the source of vibration, are costly to implement across an entire fleet and require significant upkeep. These legacy systems also struggle with accurately distinguishing between true faults and benign vibrations, which can lead to delayed or unnecessary maintenance.

Health monitoring algorithm

In an effort to tackle the problem, Trilogical has turned to AI to support development of a proprietary diagnostic tool. This seeks to make use of advanced vibration analysis to detect wheel flats in real time using a sensor mounted on the railcar body. This approach helps prevent costly damage related to wheel defects and significantly reduces unplanned vehicle or network downtime.

Recent field tests demonstrated the system's ability to detect 85% of wheel flat samples under 51 mm with zero false positives, which is a far more consistent performance than has been achieved with standard wheelset monitoring techniques. The tests were conducted through affiliate companies as part of Trilogical's global Innovation Partnership Programme, using thousands of samples collected via the RailBlazer condition monitoring platform.

The test results showed that 85% of vibration data samples from faulty railcars exhibited abnormal vibration patterns, suggesting that repeating the test on the same wagon would raise the probability of fault detection to approximately 97·8%. In contrast, 100% of the samples collected from healthy wagons exhibited no abnormal vibration patterns. By delivering this level of accuracy, operators and fleet owners can start to create a wagon health ecosystem to support their operations. This would include receiving automated alerts for early-stage wheel or structural defects, enabling maintenance tasks to be prioritised based on real-time condition data, and resource allocated accordingly.

Trilogical believes this scalable, vehicle-mounted system can help reduce derailment risks in areas already equipped with trackside sensors while offering a more cost-effective alternative to bogie-mounted sensors.

The oil train accident in south Wales in October 2020 led to considerable damage to a sensitive enviornmental site.

75
US$m

Estimated cost of damage caused by Llangennech derailment