IRSE INTERNATIONAL TECHNICAL COMMITTEE

Rail integrity is the responsibility of the permanent way: Ensuring rail integrity in the absence of track circuits

Written and edited by Alan Knight and Ian Mitchell, IRSE-ITC on behalf of the International Technical Committee of the IRSE

An important driving force for the introduction of ETCS L3 is the possibility of avoiding the need for track based train detection equipment, with its associated high lifecycle costs. In many countries track circuits are the preferred type of train detection and one reason for this is their ability to detect broken rails. However, it is important to be aware of the fact that the use of track circuits for detecting broken rails is not a feature which can be fully relied upon by railway networks. Generally they are considered to be able to detect 30 to 50% of broken rails, dependent on the track circuit and bonding used.

Rail breakages have the potential to cause very serious train accidents and in comparison to equally dangerous wrong side signalling failures rail breakages are a relatively common occurrence. When the track circuit arrived on the scene, a means of detecting clean breakages became available at no extra cost. Subsequently at least part of the responsibility for detecting rail breakages has historically been assigned to the signalling engineer and the technology at his disposal. But in the light of the present trends in train control and train detection and the drive to reduce the cost and improve the reliability of signalling equipment, it may be questionable whether this responsibility should be maintained.

Track circuits were not originally designed to detect broken rails with a high degree of dependability. But, to use modern terminology, they were relied upon to mitigate the risk. This is justifiable, of course, but it has to be ensured that the reliance on signalling equipment for the detection of breakages does not lead to a false sense of security and to otherwise unnecessary restrictions on the performance of the train detection. One example of the performance restrictions are the particularly strict regulations regarding broken rail detection in Eastern Europe, where the requirement for detecting rail breakages has led to the development of track circuits which are oversensitive to interference current. This can make the approval of modern rolling stock a nightmare. If railways do not use track circuits, what is is then required to mitigate the danger of broken rails?

To get back to basics for a moment, no rail is perfect, and even the highest quality material can contain a range of defects with impurity inclusions being the most common. In addition, defects are introduced in the field by a variety of mechanisms, including shear forces from high wheel impacts, base nicks from application of rail anchors and fasteners, and even by application of signal or traction bonding by drilling or welding.

Operating the railway “nourishes” a defect through stresses introduced by various prime forces including longitudinal expansion/contraction cycles with temperature changes, normal axle load cycling during operations, high axle load forces from defective rolling stock, lateral forces resulting from curving under-balance or hunting bogies, and impacts introduced by maintenance equipment. By reducing the stresses, the number of breakages can be potentially reduced. One means which is implemented in practice is more regular grinding of the rails which has the added advantage of reducing noise and making the ride more comfortable for the passengers.

Cracks propagating from drilled holes in the web of the rail can be avoided by drilling close to the neutral zone of the web and by deburring the holes. Sharp edges promote the formation of cracks. Experience with axle counters bolted to the web of the rail has proven the effectiveness of this means.

The real problem regarding detection of rail breakages is that electrical detection may be shutting the gate after the horse has bolted! An example of this is when the rail breaks under the train. In other cases some of the most dangerous rail breakages may not lead to a clear interruption of the longitudinal rail resistance at all. This is the case if a piece of the head of the rail breaks off and the web remains intact. This type can easily cause a derailment. Detecting rail defects before a break occurs is the predominant issue here, the clear objective is to replace the defective rail before it breaks.

Manual, periodic visual inspection provides insufficient coverage of the fault mechanisms. Only defects that have grown through to the surface provide a clue to their presence, and grease, rust, or other material can obscure the evidence. There is no clear view of the upper web, underside of the rail base and head from an inspection vehicle. Visible defects are only detectable at imminent or actual failure. Visual inspection requires possession of the track and operation of the vehicle at “inspection speed”, adversely impacting railway capacity. For these reasons visual inspection is not the solution required for a modern railway.

The widespread introduction of axle counters as a means of train detection has been one factor towards improving inspection by means of automation. Track inspection vehicles are an effective method of proactively identifying many internal defects that have not “broken through” to the surface of the rail. Technologies employed today include detecting anomalies in the magnetic field when the rail is energized with a high current, ultrasonic imaging of the internal rail structure, and EMAT. EMAT is ultrasonic inspection within a magnetic field, which enhances delectability of the defects. Today’s ultrasonic and EMAT techniques can inspect at speeds approaching ~100 kph. Ultrasonic transducers are oriented at multiple angles to the railhead, and mounted within a liquid filled rubber wheel. A liquid is sprayed on the wheel – rail interface to provide higher coupling for the ultrasonic signal. Fast Fourier transform techniques are used to produce a cross section view of the rail, with defects enhanced in color. Ultrasonic methods are effective for finding problems such as transverse defects, head and web separations, vertical split heads, and piped rail.

These methods do, however, have tradeoffs. Minute defects are present in all rails, and most will never grow to create problems. So the sensitivity setting of the equipment is important. Set to a high fault threshold, and important defects will be missed. Set too low, and a rail may be unnecessarily condemned and speed restrictions implemented, this being a regulatory requirement. A technical problem is that the ultrasonic signal cannot propagate to the outer flanges of the rail base effectively. Defects here are virtually invisible to the system. Not a perfect solution, but certainly a technical improvement over reliance on signalling.

New technologies for broken rail detection are in various stages of test. One method is to install a special fibre optic cable bonded to the rail. Theoretically this seems like a great idea, as time domain reflectometry can pinpoint a break location instantly (fibre break, that is). But the fragility of the fibre makes it difficult to maintain reliably in a railway environment.

Another idea being tested is “pinging” an acoustic wave in the rail and detecting signatures at receiver locations. Such a system was developed over the past few years in South Africa and installed on a trial basis on two of the heavy haul lines. Although it has only been operated for a limited time, it has proved to operate reliably and was successful in detect a broken rail in this period. With the current technology a broken rail detection distance of 3km is achieved. Further development aimed at increasing the detection distance and thus reducing the cost is envisaged. This holds potential, but is a long way from practical application at long distances given the noise environment in the rail.

So what are the conclusions?

Managing rail integrity does not belong to one single department in the railway. It needs to be a probabilistically based solution that combines several areas of fault coverage. Decisions need to be based on the overwhelming amount of data around rail defects and detection rates.

An education effort to share critical quality issues with permanent way staff is long overdue. This is not so easy in a vertically integrated company, let alone between independent maintenance companies. It needs to be driven from the top.

New technologies to improve rail integrity prediction and early detection of broken rails are on the horizon. But we can expect each of these will have it's own gap in fault coverage. And, of course, equipment specifically designed for detecting broken rails, will not come for free!

Every railway is looking to optimize asset life, making best use of capital investment. "Change no rail before it's time" can be heard. In order to safely extend rail life, the defect management regime must be customized for the age of the line and defect detection rate using TQM methodology.

Finally, each railway's optimised rail management regime must be customised for the type of traffic, type of infrastructure, train speeds, level of risk acceptability, and budget.

Rail integrity is primarily the responsibility of the permanent way and as such the permanent way has to be designed and maintained to reduce the likelihood of broken rails to a minimum. The means of doing this are available and have been successfully implemented with the additional result that a well maintained track provides a more comfortable ride for passengers and less wear and tear on vehicles and track.

Broken rail detection can be carried out by other means than by use of track circuits. Detecting broken rails can be included in automated inspection of infrastructure and at a relatively low cost. The absence of track circuits in ETCS Level 3, as far as broken rail is concerned, should not therefore be stopping ETCS Level 3 from happening.