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WOMEN IN RAIL: LEADERSHIP SUMMIT

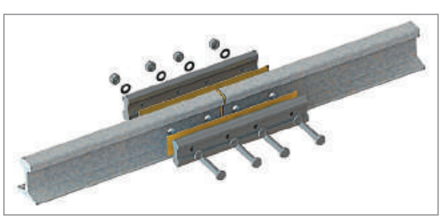
Improving the lifespan of insulated joints

Even in highly modernised railway tracks a considerable portion of signalling systems work by utilising the rail as an electrical conductor. To ensure safe and efficient operation, the rail needs to be separated into independent circuits to allow trains to be located within defined sections. Insulated rail joints (IRJs) are still the main tool used to accomplish this separation but usually require high maintenance efforts. The different static and dynamic behaviour of IRJs compared to continuous rail leads to significantly shortened IRJ life and, furthermore, to increased track deterioration and signalling malfunctions. The use of tailor-made under-sleeper pads (USPs) with designed stiffness in IRJ sections shows promising results in terms of maintenance reduction and improved service life and helps to reduce overall operational costs. MARTIN QUIRCHMAIR (R&D railway division at Getzner Werkstoffe), HARALD LOY (head of R&D railway division at Getzner, postdoc at the Intelligent Transport Systems Unit, University of Innsbruck) and CLEMENS BELL (area sales manager for Asia Pacific at Getzner Werkstoffe) explain further.

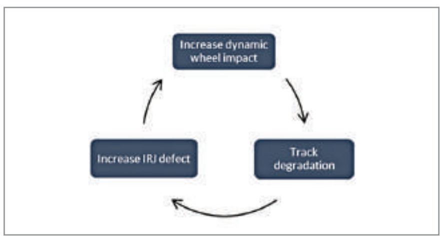
Ideally, the static and dynamic behaviour of a railway superstructure is homogeneous within the entire network. Every change in bedding stiffness leads to impacts and accelerated deterioration. Unfortunately, local stiffness changes are unavoidable due to the need of special trackwork and signalling systems.

IRJs are essential for safe railway operation and therefore are used on signalised high-density mainlines. To achieve electrical isolation, prefabricated bonded IRJs are used and welded in track. Various materials such as epoxy and Kevlar are used to create this insulation (see Figure 1).

Increased dynamic forces at IRJs and their immediate vicinity are the main cause of IRJ failure (see Figure 2). Impacts from wheels lead to increased metal flow at the rail ends (short-circuit), end post battering and degradation of ballast. Furthermore, increased



+ FIGURE 1 Principal of IRJ: rail ends are electrically insulated and bonded with fishplates and adhesives



+ FIGURE 2 Failure propagation of an IRJ defect

IRJ deflection as a result of fouled ballast induces stress into IRJ components.

On high-tonnage heavy-haul routes, IRJs may be replaced within as little as 12–18 months, which reduces the availability of the track significantly and increases overall operational costs. One approach to reduce these losses is to work on tailored solutions to keep the track quality on a high level over time and consequently increase the service life of all IRJ components.

Long-term performance due to enhanced track design

Under-sleeper pads (USPs) are well known for their potential to enhance track design in high-maintenance track sections like turnouts or transition zones. A diversified portfolio of stiffness and other mechanical properties makes USPs a viable solution to modify the static and dynamic bedding modulus of the track, which in turn helps to reduce settlement and ballast fouling. USPs can be installed within the concrete sleeper production process as well as on existing sleepers. This flexibility makes USPs suitable for new installations as well as retrofitting.

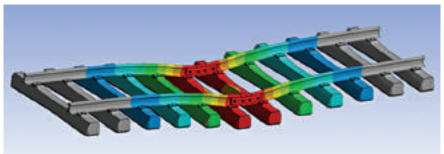
Due to these beneficial properties, USPs should be considered to improve the long-term performance of IRJs.

Model-based design

Issues at IRJs have been a topic on and off in the past. At a meeting in early 2016 between one of the largest railway operators in North America and Getzner USA Inc, an opportunity was identified as way to study this sensitive area of track. Common practice at this North American heavy-haul operator has been to install wood sleepers under IRJs in concrete sleeper track sections. However, this practice does not create a homogeneous sleeper type.

Two IRJ concrete sleeper panels were going to be installed in autumn 2016 which could be equipped with USPs. To determine the best type of USP to be used for this special application, a custom-built finite element method (FEM) model was used.

Many analytical track models calculate rail deflection and other important design parameters by using the Zimmermann method which idealises the track as an infinitely long, continuously bed-



+ **FIGURE 3** Calculated stress in IRJ panel for centre loading condition

+ **FIGURE 4** Thirty-three-tonne-axle-load heavy-haul trains operate on this track section in North America.

ded beam. These models work very well in homogeneous environments where track parameters remain unchanged. This has been verified repeatedly.

In areas with suddenly altering properties, the Zimmermann method reaches its limit as the differential equations cannot be solved analytically any more. The solution to this problem can be found in numerical models like FEM. FEM subdivides the model into a finite number of elements and solves their differential equations numerically. As a result, complex track sections like special trackwork can be analysed as a system for a holistic design approach.

The IRJ approach

Looking at the situation of an IRJ in particular, the singularity is found mainly at the IRJ itself. The difference in stiffness and mass ratio leads to extensive wear on all track components over time. In the beginning the characteristic behaviour of the IRJ is dominated by its properties, whereas after some time in revenue service the behaviour becomes dominated by continuously increasing track defects like hanging sleepers and fouled ballast.

This problem can be approached on two fronts: firstly, reduction of inhomogeneity by decreasing ballast contact pressure and dynamic loads to limit wear of all track components and, secondly, stabilisation of ballast to reduce ballast movement and improve long-term performance.

Elasto-plastic USPs are able to handle both of these issues. The FEM calculation shows that static forces at a newly installed IRJ and its immediate vicinity are reduced by roughly a quarter.

Nonetheless, the biggest benefit can be found in the intersection between ballast and the bottom of the sleeper. Unpadded sleepers show a ballast contact area of 3–5 per cent. This contact area can be increased to values up to 35pc and more, depending on the USP model.

After taking all different properties of the new IRJ and USPs into account, the FEM calculation shows that the ballast contact pressure can be reduced by 70–90pc.

Additionally, the top layer of the ballast is stabilised due to strong interlocking between the ballast and USP. Lateral track resistance is increased. Ballast movement and surface irregularities are, for the most, part eliminated.

Validation in the field

The true test of a new technical innovation is field implementation. Engineers do their very best to find the optimum computational design but performance in track determines if a solution delivers on its promises. Ballast and subsoil conditions can never be precisely predicted leaving some uncertainty in every calculation.

The test section selected has operating trains of 33t axle loads and speeds of approximately 100kmh). Measurements of the IRJ fitted with USP were taken after more than one year of revenue service.

Nearby, a standard IRJ with no USPs was selected for reference. At the control location trains operate with similar axle loads, speeds and frequency.

The set-up chosen for this measurement had a focus on rail deflection.

Deflection data during train operation is needed to achieve a fundamental understanding of the IRJ behaviour. With these findings the model can be refined for future calculations and the quality of the solution improves accordingly.

Rail deflection was measured at four different locations.

Evaluation and results

Due to the different configuration of each train the evaluation is based on the locomotives, which show similar axle loads for all measured trains.

In order to obtain statistically significant results for every single sensor an average of the maximum deflection of the first three axles of all trains was used. This way the benefit of the solution in terms of stiffness adjustment can be seen in Figure 5.

The IRJs perform differently to the adjacent track. However, the IRJ itself shows less deflection with USPs compared to the control location. This phenomenon can be explained by looking at track alignment and surface over time. USPs are well known to reduce ballast movement and, furthermore, increase track stability. The development of track defects is prevented and, as a consequence, the deflection at the IRJ location remains constant over time.

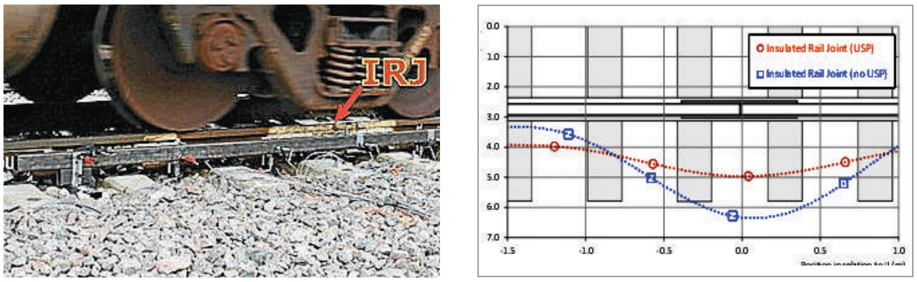
Conclusion

IRJs violate the homogeneity of railway tracks, which results in high dynamic stress and subsequently in IRJ failure.

In 2016 one of the largest heavy haul railway operators in North American decided to test a new solution for this high-maintenance track section by installing IRJ concrete sleeper panels equipped with elasto-plastic polyurethane USPs. Getzner Werkstoffe used its expertise to design elasticity for special trackwork and provided tailored USPs based on modern FEM simulations.

The benefits of this solution regarding long-term track alignment were validated by in-field measurements in one of the largest heavy-haul networks in North America.

IRJ concrete sleeper panels equipped with elasto-plastic polyurethane USPs show a more uniform rail deflection compared to standard IRJs panels. Stress within the IRJ and ballast is reduced, which leads to less maintenance, higher track availability and a more cost-efficient operation. T+S



+ **FIGURE 5 LEFT** Rail deflection was measured at four locations close to the IRJ. **RIGHT** More uniform rail deflection of padded IRJ (○) versus non-padded IRJ (□) in the immediate IRJ vicinity leads to extended long-term performance.