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Laboratory and Field Validation of Novel Conductive Adhesion Enhancing Materials for Railroads

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Abstract

Sufficient adhesion in a wheel-rail contact is one of the key requirements for safe and efficient railway operations. Low adhesion conditions significantly increase the risk of braking issues leading to extended braking distances, passing signals at danger, reduced acceleration rate, and damage to the wheels and rails. Sanding remains one of the most common methods to overcome low adhesion conditions. However, over application of electrically insulating sand may interfere with railway track circuits of some signalling systems leading to loss of train detection and therefore limits of application have been imposed. The development of alternative, novel adhesion enhancing materials with higher electrically conductivity may mitigate the risk of electrical insulation and allow for larger amounts of material to be applied to improve wheel/rail adhesion. As well as not interfering with track circuits, these new materials must demonstrate good deposition efficiency using conventional sanders as well as providing a significant increase in friction levels under low adhesion conditions. This work describes the testing of proprietary coatings which can be applied to sand and other particles to improve conductivity and deposition efficiency. Laboratory scale testing of the deposition efficiency, adhesion enhancing and electrical characteristics of these materials were carried out at the University of British Columbia and LB Foster facilities in Canada and field testing of the influence on track circuits was carried out in the UK by The University of Sheffield under an RSSB funded project. Laboratory results indicated an improvement in deposition efficiency compared to non-coated particles as well as improved electrical conductivity in comparison with standard sand with no reduction in adhesion enhancement performance. Field trials showed that, even at relatively high deposition rates, train detection in track circuits was unaffected which may allow such materials to be used at higher application rates to further increase adhesion without any risk to train operations. Further work to test these materials has been proposed including flow characteristics in equipment and full scale braking tests under a range of low adhesion conditions.

Keywords: adhesion, sanding, conductive, materials

1 Introduction

Sufficient adhesion in a wheel-rail contact is one of the key requirements for safe and efficient railway operations. Low adhesion conditions may hamper the transportation process in many ways causing extended braking distances, reduced acceleration rate, and damage to the wheels and rails. Sanding remains one of the most common methods to overcome low adhesion conditions on railroads [1]. However, it is well-documented that application of electrically insulating sand may interfere with railway track circuits of some signalling systems, which rely heavily on good wheel/rail interface conductivity [1,2]. Thus, to reduce the risk of wheel/rail insulation, a limit of 7.5 g/m was set as the maximum sand application rate on the UK rail network (GMRT2461) [3]. The development of alternative adhesion enhancing materials with higher electrically conductivity may mitigate the risk of electrical insulation and allow for larger amounts of material to be applied to improve wheel/rail adhesion. In addition to not interfering with the track circuits, these materials must also demonstrate good deposition efficiency using conventional sanders and provide a significant increase in friction levels under various low adhesion conditions. The current work describes the use of a proprietary coating, which can be applied over sand and other particles to improve conductivity and deposition efficiency of these materials.

The performance characteristics of these novel, coated adhesion-enhancing materials were studied in the laboratory and field trials. To study the impact of particle coating on particle conveying into the wheel/rail nip, a half-scale sander/wheel was tested in the laboratory, and the deposition efficiency of coated and uncoated particles was compared. Preliminary adhesion enhancing and electrical conductivity properties were studied using a twin disc instrument under simulated wheel/rail interface conditions, and the interference with track circuits was examined during field trials, which were carried out at a heritage railway site in the UK.

2 Methods

In order for coated or uncoated particles to serve as traction enhancers, they must first be directed by a locomotive sander into the wheel/rail nip. In laboratory experiments conducted at the University of British Columbia, a half-scale sander and train wheel were mounted above a moving steel belt, representing the rail. A variety of granular materials, including conventional sand, were tested in the sander. The scaled sander-mass-flow-rate and train speed were set to typical operating values, and the sand passing through the wheel-rail nip was measured gravimetrically. High speed imaging of the sand, combined with Particle Tracking Velocimetry, was used to measure the velocity of the sand particles.

Adhesion enhancing and electrical conductivity studies were performed using a Phoenix Tribology TE72 twin disc instrument. The discs are electrically isolated from each other, which allows creation of a millivolt potential in a Lunn-Furey electrical contact resistance circuit. Application of conductive materials into the contact area of two discs does not disturb the circuit (contact potential ~ 0 mV). Application of non-conductive materials results in full electrical insulation of the discs (contact potential ~52 mV). The ability of adhesion enhancing materials to increase friction levels was studied by application of 100 mg of test products into the contact area of two discs contaminated with soap. All of the twin disc experiments were run at 20 rpm disc speed, ~1000 MPa contact pressure and 10% slip.

As part of RSSB funded project COF-UOS-03 [4], field trials were carried out at a heritage railway site in the UK where a low voltage (0.5VDC), 201 m long track circuit was used to test the track circuit insulation behaviour of the novel adhesion materials. The relay voltage was fed into a trackside cabinet where it was measured and logged. A class 20 locomotive was used for the trials.

Pre-weighed amounts (3.75g/m, 7.5g/m, 10g/m and 15g/m) of the novel adhesion particles (and a standard rail sand for reference) were manually applied to the track, over a measured length of track which was at least twice the length of the wheelbase of the locomotive. The locomotive travelled through the test track at a constant speed of 10 mph and measurements were taken throughout the vehicle pass and return. Static, over application tests were also made where the rail ahead of each locomotive wheel was completely covered by the material and the vehicle driven onto the material and track circuit measurements taken.

3 Results

The deposition efficiency of a sander is the ratio of the mass flow of particles through the nip to the mass flow out of the sander. Sander deposition efficiency results are summarized in Figure 1. For all the granular materials tested the deposition efficiency is substantially greater (from 7%-29%) for the coated particles relative to the uncoated particles.

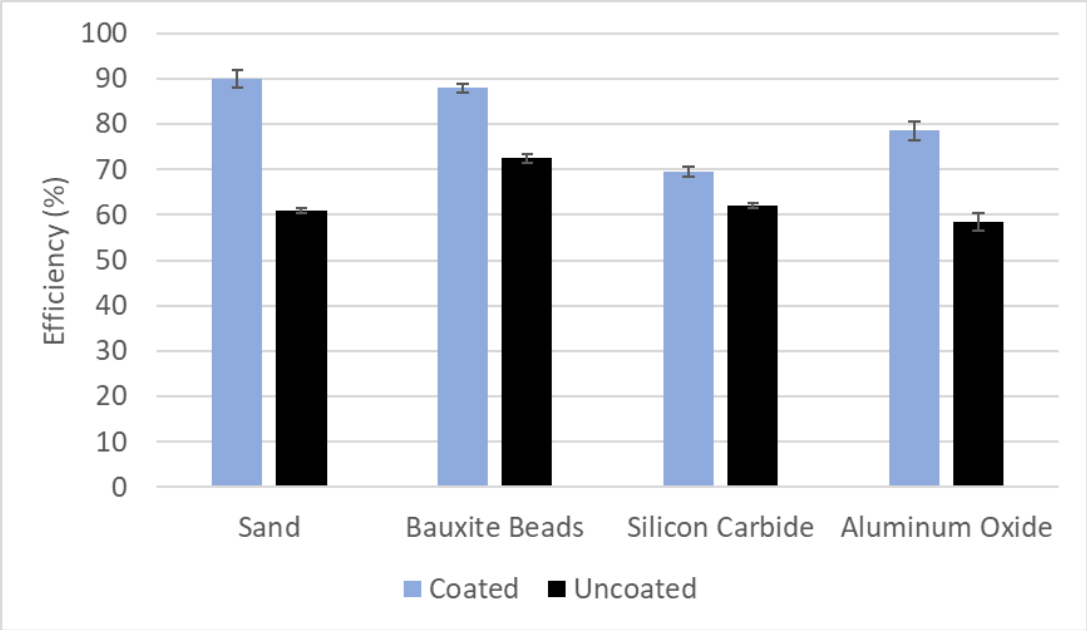

Figure 1. Deposition efficiency of coated and uncoated particles.

Related work [5] has shown that the deposition efficiency is strongly correlated with the lateral spread of the particle jet from the sander, with higher deposition efficiencies corresponding with a tighter spread of particles. An example of the relatively tighter spread of coated particles from the sander nozzle is shown in Figure 2. The coated sand trajectory traces from the sander in Figure 2(a) fill a much smaller cone angle than do the uncoated sand trajectories of Figure 2(b).

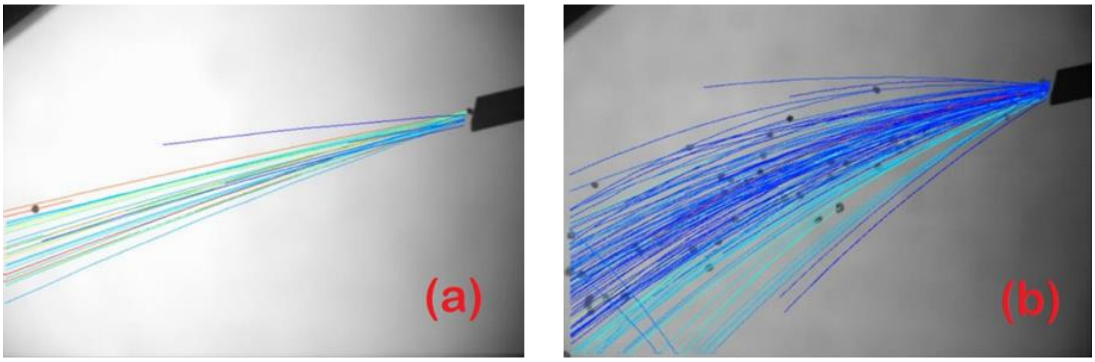

Figure 2. Particle tracking velocimetry particle trajectories of (a) coated and (b) uncoated silica sand[5]

Laboratory twin-disc experiments under simulated low adhesion conditions demonstrated a substantial increase in overall friction levels with application of coated materials as shown in Figure 3. Based on these data, coated aluminium oxide and bauxite demonstrated the highest friction levels in these experiments, which could be a result of overall higher hardness of these materials.

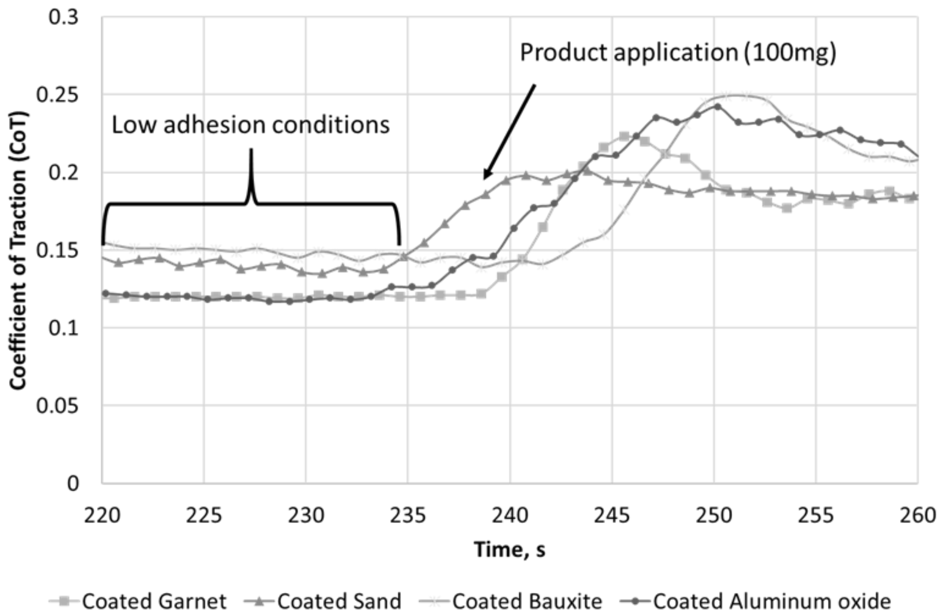

Figure 3. Performance of coated materials under simulated low adhesion conditions (soap) measured by the twin-disc instrument.

To demonstrate the effect of coating on conductivity, both coated and uncoated garnet were tested using the twin disc instrument under simulated wheel/rail interface conditions. As shown in Figure 4, uncoated garnet shows a significant increase in contact potential up to almost the full electrical insulation of the two discs. In contrast, application of coated garnet does not cause any significant electrical insulation as the contact potential remains relatively stable at low levels.

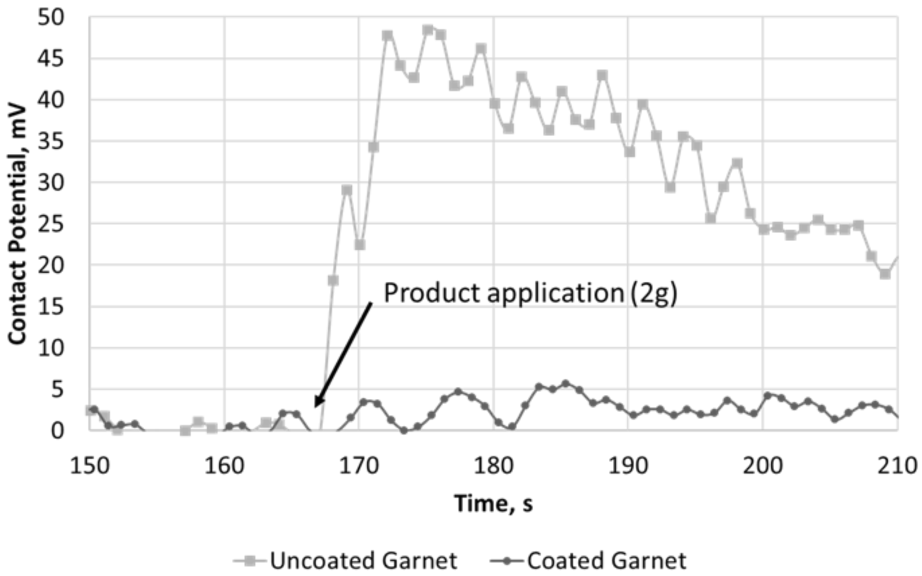

Figure 4. Contact Potential/Conductivity testing using twin-disc instrument.

The interference of these materials with actual track circuits was examined during field trials in the UK. In Figure 5, application of standard rail sand results in significant wheel/rail electrical insulation. In contrast, application of novel coated materials, such as coated aluminium oxide in Figure 6, did not cause any major interference, significantly reducing the risk of loss of train detection.

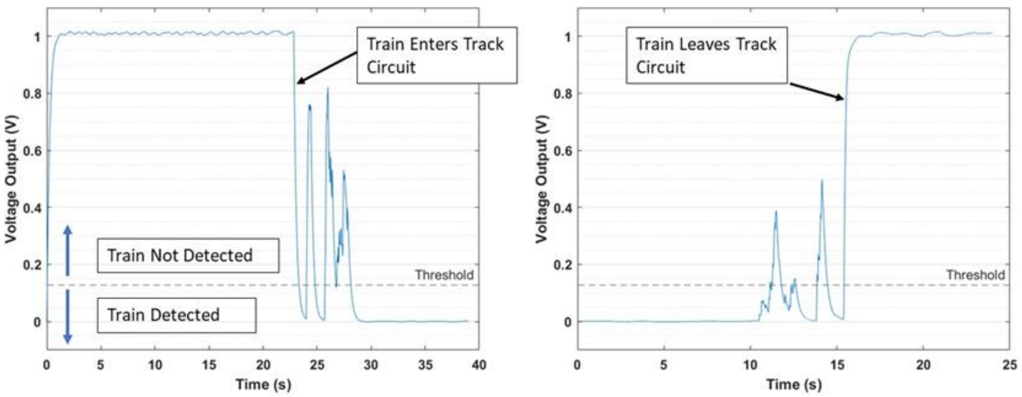

Figure 5. Field trial results for standard rail sand at 7.5g/m (Left) First pass, (Right)second pass [4]

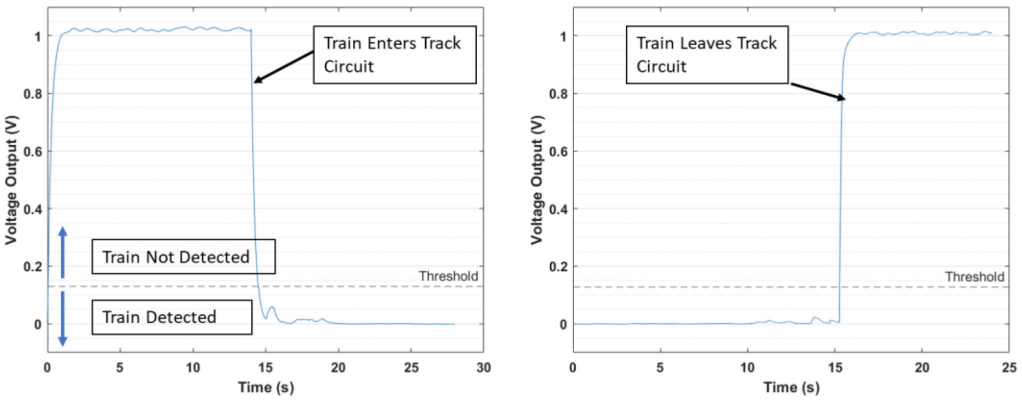

Figure 6. Field trial results for coated aluminium oxide @ 7.5g/m (Left) First pass, (Right)second pass [4]

4 Conclusions and Contributions

Half scale sander testing found that using a conductive coating improves the deposition efficiency of adhesion enhancing materials, which may reduce product wastage during application, and coated particles deposit more efficiently into the wheel-rail nip than do uncoated particles. The reasons for these differences are not known, but may be due to the different particle-particle and particle-wall interactions inside the sander nozzle, for the two types of particles.

Laboratory twin disc and field trials of novel, coated adhesion-enhancing materials demonstrate significantly improved electrical conductivity for these products in comparison with standard sand. The higher conductivity reduces the risk that the adhesion-enhancing material will interfere with the electrical continuity of the signalling system used for train detection. The reduced risk of wheel/rail insulation may allow the product to be applied at rates higher than the current standard maximum application rate of 7.5 g/m on the GB railway system for standard sand. These higher application rates may provide rapid restoration of adhesion levels required for efficient braking and traction performance. In the field trials, coated materials produced less loss of train detection in comparison to the standard rail sand, which caused some degree of wheel/rail insulation at all tested amounts. Coated aluminium oxide produced no loss of train detection up to the maximum application amount tested, 15 g/m. The field trials also revealed the importance of the initial stages of crushing on wheel/rail resistance, as during second passes of the train the resistance was markedly reduced as the wheels rolled over previously crushed materials.

Further extensive testing is required for full validation of the novel adhesion enhancing materials, which should include both laboratory and field trials under different low adhesion conditions, studies of flow properties of new particles through conventional sanders, electrical interference with insulated joints on the tracks and other track and rolling stock equipment, and braking characteristics compared to conventional sand.

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References

[1] Skipper, WA, Chalisey, A, Lewis, R., "A review of railway sanding system research: Wheel/rail isolation, damage, and particle application" Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, vol 234, no. 6, 567–583, 2020.

[2] Skipper, WA, Chalisey, A, Lewis, R., "A review of railway sanding system research: adhesion restoration and leaf layer removal" Tribol Mater Surf Interfaces, 12, 237–251, 2018.

[3] Rail Safety and Standards Board, "GMRT2461 Sanding Equipment (Issue 3)." pp. 1–24, 2018.

[4] Rail safety and Standards Board, "Sand consist changes for improved track circuit performance (COF-OS-03 Report), 2021. [online] Available: https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=27535

[5] Roberts, J.J. and Green, S.I., "Experimental Study of Locomotive Sanding", Proceedings of the IMECH E Part F: Journal of Rail and Rapid Transit, vol. 235, no.3, pp. 265-274, 2021.