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Structural and Microstructural Analysis of White Etching Layer Formation by Electrical Arcing Induced on the Surface of Rail Track

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Abstract : A number of studies have focused on the formation mechanics of white etching layer and its origin in the railway operation. Until recently, the following hypotheses consider the precise mechanics of WELs formation: (i) WELs are the result of thermal process caused by wheel slip; (ii) WELs are mechanically induced by severe plastic deformation; (iii) WELs are caused by a combination of thermo-mechanical process. The mechanisms discussed above lead to occurrence of white etching layers on the area of wheel and rail contact. This is because the contact patch which is the active point of the wheel on the rail is exposed to highest shear stresses which result in localised severe plastic deformation; and highest rate of heat caused by wheel slipe during excessive traction or braking effort. However, if the WELs are not on the running band area, it would suggest that there is another cause of WELs formation. In railway system, particularly electrified railway, arcing phenomenon has been occurring more often and regularly on the rails. In electrified railway, the current is delivered to the train traction motor via contact wires and then returned to the station via the contact between the wheel and the rail. If the contact between the wheel and the rail is temporarily losing, due to dynamic vibration, entrapped dirt or water, lubricant effect or oxidation occurrences, high current can jump through the gap and results in arcing. The other resources of arcing also include the wheel passage the insulated joint and lightning on a train during bad weather. During the arcing, an extensive heat is generated and speared over a large area of top surface of rail. Thus, arcing is considered another heat source in the rail head (rather than wheel slipe) that results in microstructural changes and white etching layer formation. A head hardened (HH) rail steel, cut from a curved rail truck was used for the investigation. Samples were sectioned from a depth of 10 mm below the rail surface, where the material is considered to be still within the hardened layer but away from any microstructural changes on the top surface layer caused by train passage. These samples were subjected to electrical discharges by using Gas Tungsten Arc Welding (GTAW) machine. The arc current was controlled and moved along the samples surface in the direction of travel, as indicated by an arrow. Five different conditions were applied on the surface of the samples. Samples containing pre-existed WELs, taken from ex-service rail surface, were also considered in this study for comparison. Both simulated and ex-serviced WELs were characterised by advanced methods including SEM, TEM, TKD, EDS, XRD. Samples for TEM and TKFD were prepared by Focused Ion Beam (FIB) milling. The results showed that both simulated WELs by electrical arcing and ex-service WEL comprise similar microstructure. Brown etching layer was found with WELs and likely induced by a concurrent tempering process. This study provided a clear understanding of new formation mechanics of WELs which contributes to track maintenance procedure.

Keywords : white etching layer, arcing, brown etching layer, material characterisation
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