FATIGUE LIFE PREDICTION OF THE RAIL UNDERHEAD REGION

INFLUENCED BY WEAR IN HEAVY HAUL OPERATIONS

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Severe head wear combined with a transverse defect is considered as an increased risk for rail safety and integrity, and reverse detail fracture (i.e. transverse defects which initiate at the lower corner of the gauge face of heavily worn rail) could be produced. This defect type as observed in poorly lubricated, heavily worn curved rails on stiff track subjected to high axle loads is shown in Fig 1[1, 2]. Such failures which initiate at the underhead radius at aluminothermic welds are found in heavy axle load railway operation in Australia. Although, the weld normally has the lower material strength, the elevated residual stress levels and the complex geometry leading to stress concentration, the reverse detail fracture occasionally seen in aluminothermic welds but generally occur in the rail underhead [3].

Fig. 1 Reverse detail fracture at the lower gauge corner on heavily worn rail [Courtesy of the Transportation Safety Board of Canada with the permission of the Minister of Public Works and Government Services [4]]

It is believed that the behaviour of reverse detail fractures is caused by the longitudinal bending stresses at the underhead radius (lower gauge corner of rail). In the field measurements, it was reported that the tension spikes at the gauge side underhead radius reached a peak value of about 100 MPa when the wheel was directly above the strain gauge position (underhead offset of measurement point 20 mm). These tension spikes are generated because of vertical and lateral head bending on the web. This effect is highly localized and is additional to the stresses generated due to vertical and lateral bending of the whole rail profile (the so called global bending). These stresses can drive an initiation and propagation from the underhead radius.

Research conducted in a previous studies [5, 6] reveals that the tension spike is strongly dependent on the contact patch location and the magnitude and direction of the lateral traction, and hence on curving and hunting behaviour of the vehicle. The tension spike at the underhead radius of the rail can cause fatigue damage and cracking. In addition, the
presence of such high tensile stresses can cause a crack to turn perpendicular to these tensile stresses and result in the formation of transverse defects. Currently, Australian heavy haul rail systems operate with axle loads of up to 35 – 40 tonne. The previous analysis with an axle load of 35 tonnes considered an unworn rail head. The current work extends this analysis to consider the effect of worn rail profile on longitudinal stresses and their effect on fatigue behaviour in the underhead region of the rail head. The effect of residual stresses is also incorporated in this work.

Figure 2 shows a schematic describing the development of the model for this study. Effect of contact patch offset from the rail centreline, the (L/V) ratio of lateral (L) to vertical (V) loads, the direction of lateral shear traction, the thermal and residual stresses are considered using a Finite Element method. A fully slipping elliptical Hertizan contact patch was modelled for this FE work and is used to calculate the stress state and fatigue damage.

The Dang Van criterion as damage parameter programmed into ABAQUS subroutine, UVAR (user output variables), is used to identify a critical plane for any potential fatigue crack at the specified location. The analysed data were compared by the measured data to verify the FE model.

**Keywords:** underhead radius stresses, multi-axial fatigue, finite element method, rail wheel contact, rolling contact fatigue, worn profile, heavy haul operations
References:


