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Modelling of fatigue crack propagation induced by railways traffic in the rail head

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Summary

A global approach is developed for studying the fatigue phenomena a?"initiation and propagation- induced by repeated rolling, or rolling-sliding contacts between wheel and rail. Cracks initiate and propagate in the rail head in a complex varying multiaxial stress regime due to hertzian or non hertzian contacts generating 3D residual stress pattern. This paper focus on a particular aspect of a research program involving French and German railways companies devoted to the modelling of defects induced in the rails by the traffic. Modelling of crack propagation induced by contact between solids is a very important topic but very difficult to simulate, because most of the time, it occurs under complex multiaxial loading. In the case of rail head cracks, stresses of different nature intervene: bending stress, thermal stress, contact stress and residual stress. In order get round these difficulties, some a?oengineeringa?? approaches take only some of these stresses into account. For instance if one consider only bending stress and thermal stress, the crack propagation problem is then simplified; under the load, the stress state is mainly compressive and an other type of proposal consists to take account of the tangential traction stress induced by the wheel and to consider that the surface cracks propagate in mode II and III. However, these hypotheses are not satisfactory, particularly in the case of internal cracks propagating downwards (kidney shape cracks, cracks initiated by squatsa?|). First the tension bending stress in the rail on the track is rather small and it is in no ways sufficient alone to make the cracks propagate; second friction phenomena exist in presence of compression and they are not taken into account. The rail crack propagation modelling presented in this paper differs completely from existing approaches. In particular, only mode I cracking is involved and there is no need of very high bending stress to make the crack propagates in the rail head due to traffic loading. This result match the observations made on the track In this modelling, thermal stresses, residual stresses and elastic stresses induced by the traffic (bending, contact stressesa?|) intervene. The introduction of residual stresses in the calculations presents some difficulties, since the measured residual stresses are not self equilibrated. Moreover, this residual stress field is modified by the presence of the crack. In our modelling, instead of stresses, we introduce the stabilised incompatible plastic strain distribution which is at the origin of the residual stresses and which does not depend on the crack. The stabilised residual stress distribution and the corresponding plastic strain distribution are obtained by direct calculations using a specific elastoplastic algorithm we have developed previously, the stationary algorithm.* The scenario of fatigue crack propagation is the

following: under the wheel, the stress field is mainly severe compression so that the crack is closed; when the wheel moves off, the crack opens progressively due to the thermal stress induced by temperature variations, the residual stress and the positive bending stress. The maximum of the crack opening position corresponds to the maximum of positive bending stress. The material coefficients of the fatigue crack propagation law, of Paris type, are obtained by interpreting the experiences on artificially cracked rail done by the German Research Institute BAM. These coefficients are consistent with those obtained directly by classical laboratory fatigue propagation tests. A a?ostructural Paris lawa?? is thus derived for railways applications. Comparisons between observations on the track and results of predictive 3D calculations are presented.

* K. Dang Van and M.H. Maitournam, Steady-State flow in Classical Elastoplasticity: Applications to Repeated Rolling and Sliding Contacta, JMPS, Vol.41, NA?11, pp.1691-1710, 1993.