Rail fatigue stochastic modelling

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Abstract:

The dynamical response of a train rolling on a real track depends on several parameters. Most of them cannot be accurately identified and have to be considered as uncertain and the wheel-rail contact parameters cannot be completely characterized using deterministic models. The aim of this paper is the construction of a probabilistic model of the rail fatigue life considering the track geometry as a random field indexed by the space (curvilinear abscissa of the track) and statistically representative of the considered railway network.

The features of this random field are identified using measurement data. Using the Karhunen-Loève expansion, a random field can be approximated by its truncated projection on an orthogonal basis. In this way it is expressed as a sum of a finite set of deterministic spatial functions multiplied by random decorrelated coefficients. Then, the multivariate distributions of the random projection coefficients of the basis are characterized using the Polynomial Chaos Expansion (PCE). This consists in expanding the random coefficients in a sum of deterministic coefficients multiplied by a polynomial basis of a multivariate random variable (called germ) whose probability density function is known. The PCE deterministic coefficients are identified via log-likelihood maximization [3]. In this way, by generating the polynomial chaos germs, it is possible to obtain independent realisations of the field.

The tracks thus generated are introduced as the input of a railway dynamics software (*SIMPACK*) to simulate the passage of the vehicle on a curved track with geometric irregularities. In this way the rail-wheel contact forces and the surface stresses fields are computed in each location of the spatial domain. Since the computational time is low, the statistics of the parameters on which the contact patch depends are obtained by Monte Carlo simulations.

Using the surface stresses calculated in the previous step as boundary condition, a finite element calculation allows to compute the stresses inside the rail in a fixed location of the spatial domain. After repeated passages of the train the plastic strain field is stabilized, i.e. it does not vary after another passage. Using the algorithm proposed in [1] the stresses corresponding to this steady state are obtained and a fatigue criterion is applied on them. Since this step is computationally very expensive, different meta-modelling techniques [2] are employed and compared to estimate the fatigue index in the complete spatial domain. Then, through a variance-based global sensitivity analysis [4], the influence of the track irregularities on the variation of the rail life is analysed. The aim is to identify which kinds of irregularities have a more important impact on the contact patch variations and so on the fatigue life. This study is replicated for different curve classes (by varying the design curve radius and the associated superelevation) and train operational conditions (passengers load and velocity).

References

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Short biography – Alfonso M. Panunzio received the degree in engineering from Ecole Centrale de Lyon (France) ant Politecnico di Torino (Italy) in 2014 and is currently PhD candidate at CentraleSupéc (France). His PhD is founded by RATP, the public urban transport company of Paris. His doctoral work investigates on the fatigue life of the rails in order to construct a stochastic model to improve the track maintenance policy.