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Role of air humidity in residual fatigue lifetime of railway axle

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The inspection intervals are often set according to Damage tolerance approach, where a potential crack in a railway axle is considered to ensure safe operation even if some defect is present. This work is focused on development of optimized Damage tolerance model for prediction of residual fatigue life (RFL) of railway axles with consideration of oxide debris at fracture surfaces. Correct prediction of fatigue crack growth rates is essential for RFL predictions, which in turn allows better optimization of inspection intervals. The fatigue crack growth threshold influences low growth rates, which is especially important for RFL of railway axles due to high occurrence of loading amplitudes near or below the threshold. Threshold value of railway axle steels is affected by many factors such as loading history, loading frequency, etc. The contribution shows influence of the air humidity and consequent oxide debris formation at fracture surfaces on threshold values for fatigue crack propagation in railway axle.

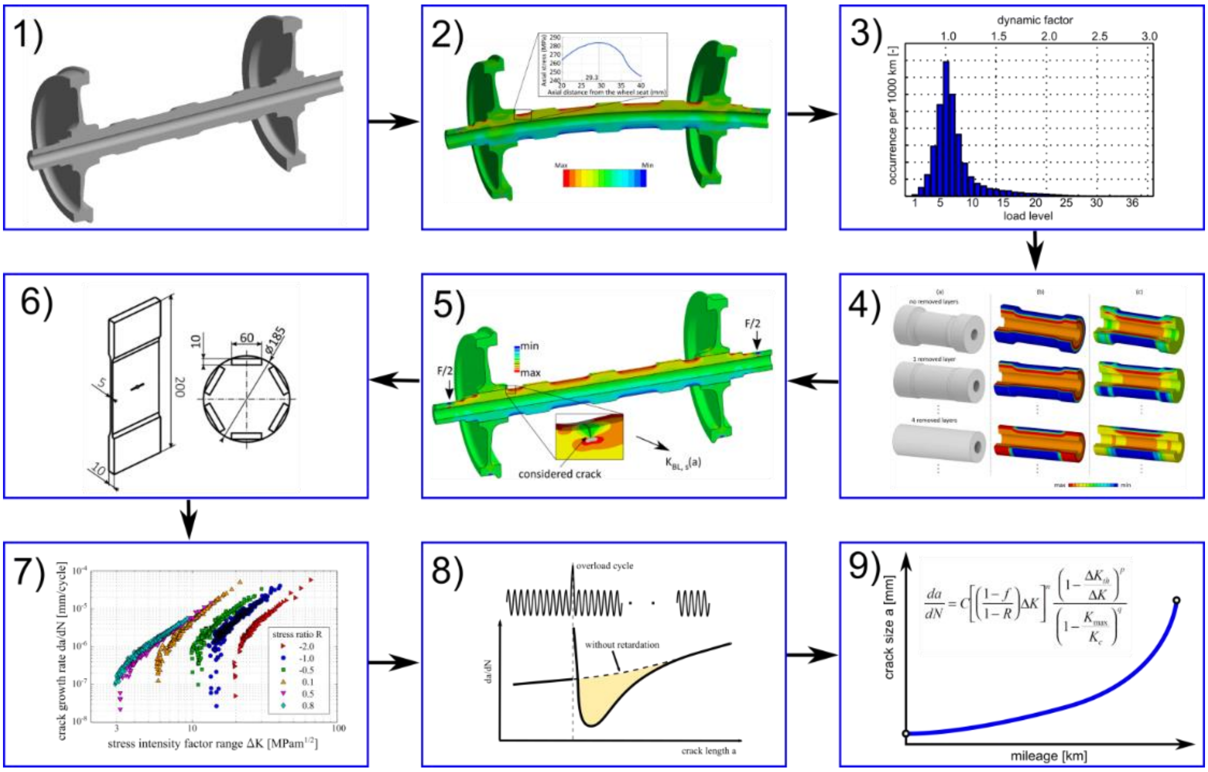

Fig. 1. Scheme of methodology of prediction of residual fatigue lifetime of railway axle

During years Institute of Physics of Materials CAS (IPM) and Bonatrans Group developed own procedure for estimation of residual fatigue lifetime of railway axles, see Fig.1. This complex methodology covers:

1) Modelling of railway axle geometry,
2) Finite element model of studied wheelset. Numerical calculations lead to the investigation of critical areas,
3) Determination of load spectrum and interference between axle and wheel,
4) Determination of residual stresses based on own experimental and numerical approaches,
5) Determination of fracture parameters of propagating fatigue crack: stress intensity factor solutions for bending load, press-fit load and implemented distribution of residual stress,
6) Preparing for an experimental campaign,
7) Experimental determination of fatigue crack propagation rates (da/dN-ΔK curves) for all load ratios and humidity conditions in service,
8) Inclusion of other influences: e.g. retardation effects,
9) Use of NASGRO approach [1] based on Newman´s equation [2] for residual fatigue lifetime determination,
10) Validation of the results. Comparison with full scale experimental meauserements.

The contribution presented will show the influence of air humidity during determination of material properties or during train operation. Experimental data obtained under different air humidity conditions were used in the methodology introduced above and important difference in RFLs for different air conditions were obtained. It will be show that the humidity of the air belongs to the main parameters influencing fatigue crack behaviour during fatigue loading.

Collaboration between the Institute of Physics of Materials, the Czech Academy of Sciences and the Bonatrans Group has yielded exciting results. Some factors influencing the residual fatigue lifetime estimation of railway axles were found to be extremely significant. At the same time, these factors are not taken into account in traditional computational approaches. In particular, the first one is compressive residual stress, commonly induced in the surface layers of railway axles. The second one is the crack growth threshold, which is not constant, even for a constant load ratio. Its fluctuation due to air humidity can lead to changes in residual fatigue lifetime of one or two orders of magnitude. Computational models taking these effects into account have been recently developed at the Institute of Physics of Materials, as well as experimental procedures to obtain the necessary material inputs. It was found that conditions in usual fatigue testing laboratories may lead to non-conservative threshold values. This problem can be overcome by using of the original special sealed chamber for modification of air humidity. In this way, the conditions for lower threshold can be simulated, which is relevant for some conditions in operation. It will avoid using of non-conservative values in the theoretical estimations of residual fatigue lifetimes of railway axles.

Acknowledgement

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References

[1] NASGRO, Fracture mechanics and fatigue crack growth analysis software, 2002.
[2] Newman, J. C., A crack opening stress equation for fatigue crack growth, Int. Journal of Fracture 24 (1984) 131-135.