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Lifetime estimation of polyoxymethelene under mixed-mode loading conditions

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Roller bearing elements made of polymer materials started to become more frequently used in the recent past, thanks to their specific advantages. Such as good noise reduction or their suitability for smaller-sized parts. Though the application of such bearings is limited by number of the load cycles and possible load levels. As a result of manufacture process, they contain small voids and additional internal stresses. Fatigue cracks are mostly initiating from these defects, while it is important to note, that the cracks in bearing elements are exposed to mixed-mode loading conditions. However, studies of the mixed-mode conditions are a bit problematic, namely because these conditions are often times difficult to achieve and also cracks tend to deviate from the original trajectory. This fact brought an idea of trying to observe, if the mode I data are applicable for mixed-mode conditions, or if there is any relation between these scenarios. Therefore, the main focus of this study was to compare lifetimes – experimentally measured under mixed-mode conditions with numerically predicted ones, that has been based on the data, produced on mode I conditions. Also FEM model was implemented in this study.

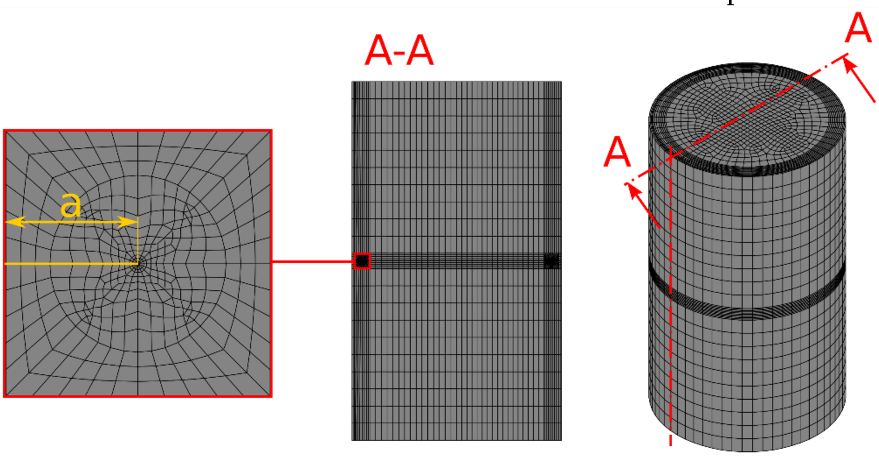

Fig. 1. Meshed specimen geometry

Cracked round bar (CRB) specimens were used for experimental purposes, as this type of specimen provides clear combination of loading modes I + III, when loaded by tension + torsion. However, knowledge of the crack growth rates is necessary for further lifetime predictions. Usually it is very difficult to obtain usable crack growth rates under mixed-mode loading conditions. Therefore, this is how mode I data were implemented in this study. Because the crack growth rates were measured on the tension-only loaded CRB specimens – mode I loading conditions. Crack growth rates were also measured on compact tension (CT) specimens, since these are easier to experiment with and linear part of the v-K curves is much more significant.

FEM numerical simulations were carried out in ANSYS APDL software. Fatigue crack propagation was described by small scale yielding conditions, therefore LEFM approach was applied. Linear elastic material model was used with elastic constants of the polyoxymethelene, more specifically Young's moduli was 4600 MPa and Poisson's ratio was 0,45. Meshed specimen with detailed cross section of the crack front area is displayed in Fig. 1. Boundary conditions were set according to experiment – bottom surface was fixed, while upper surface was loaded by tension and torsion. Main focus of the numerical simulations was the calculation of the stress intensity factors K_I and K_{III}. Thanks to knowledge of the stress intensity factors, the K-calibration was carried out for different crack lengths in range of the experimental data. Based on this data, effective stress intensity factor range was evaluated. Finally, comparison of the experimentally measured lifetimes of the mixed-mode CRB specimens with numerically predicted ones, that were based on crack growth rates, measured on tension loaded CRB specimens and CT specimens was carried out, see Fig.2.

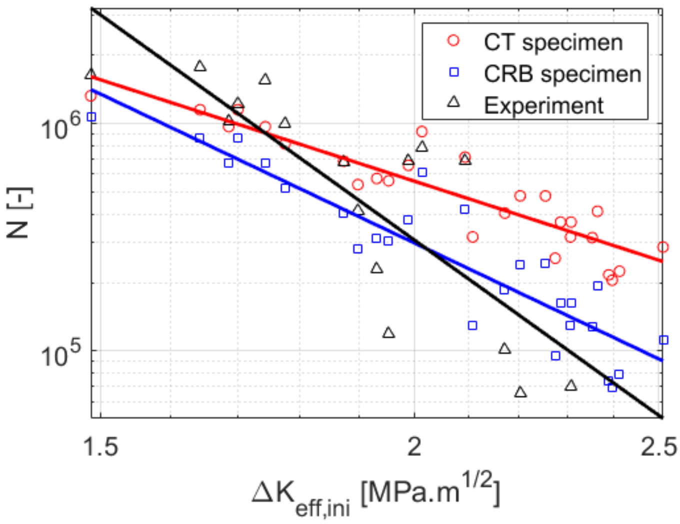

Fig. 2. Dependence of the lifetimes on the initial effective stress intensity factor

In order to do that, additional parameter had to be implemented, against which the lifetimes could be plotted. For these purposes the initial effective stress intensity factor was used, as it is best reflecting the initial loading conditions, which have the highest impact on lifetimes themselves.

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