Study of the effects of air and seawater environments on fatigue behavior of natural rubber

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Natural rubber (NR) is widely used in marine application due to its high deformation, low water absorption, and consistent mechanical properties after prolonged submersion in seawater. Typically, components made from natural rubber suffer from fatigue failure due to prolonged cyclic loading.

In order to study the fatigue behavior of NR, uniaxial fatigue life and crack propagation experiments were carried out in addition to microscopic analysis of the fatigue damage mechanisms with scanning electron microscopy (SEM). The experiments explored the influence of the R-ratio of R=0 and R=0.2 (relaxing and non-relaxing loading conditions, respectively) and the level of loading in conjunction with the environment – seawater and air as control. The importance of the R-ratio is characterized by increased presence of strain-induced crystallization (SIC) for non-relaxing loading conditions. The fatigue life tests in both environments were performed in similar conditions at a frequency of 2 Hz and at 4 levels of oscillating amplitude. The fatigue life tests were performed on standard dumbbell specimens and the crack propagation tests on single edge notched (SEN) specimens.

Primarily – for relaxing testing conditions (R=0) – experimental results for fatigue life (Figure 1) and crack growth behavior are almost identical. Similarly, microscopic analysis of the specimen surfaces points to analogous damage mechanisms in both environments.

Secondly – for non-relaxing testing conditions – the beneficial effect of SIC for non-relaxing conditions is observed in both environments and for both types of experiments: fatigue life – increased duration; crack propagation – increased fatigue threshold and decreased crack growth rate. Furthermore, at higher amplitudes, the fatigue life of NR in seawater is greater than in air despite having almost identical crack growth behavior in both environments. Therefore, it seems that that the difference in the fatigue life is due to the environmental effects on crack initiation with air environment being more damaging and influencing earlier crack initiation. Correspondingly, microscopic analysis of the specimen surfaces (Figure 1) shows presence of two different cracking mechanisms in the two environments. Observed on air tested specimens, the first mechanism is typical to that of environmental damage due to ozone or oxygen with numerous surface and edge cracks of various sizes that are perpendicular to the loading direction. In the seawater environment, comparable environmental damage is practically absent, but cracks of irregular shape are observed; mechanisms for formation of such cracks are put forward for discussion.

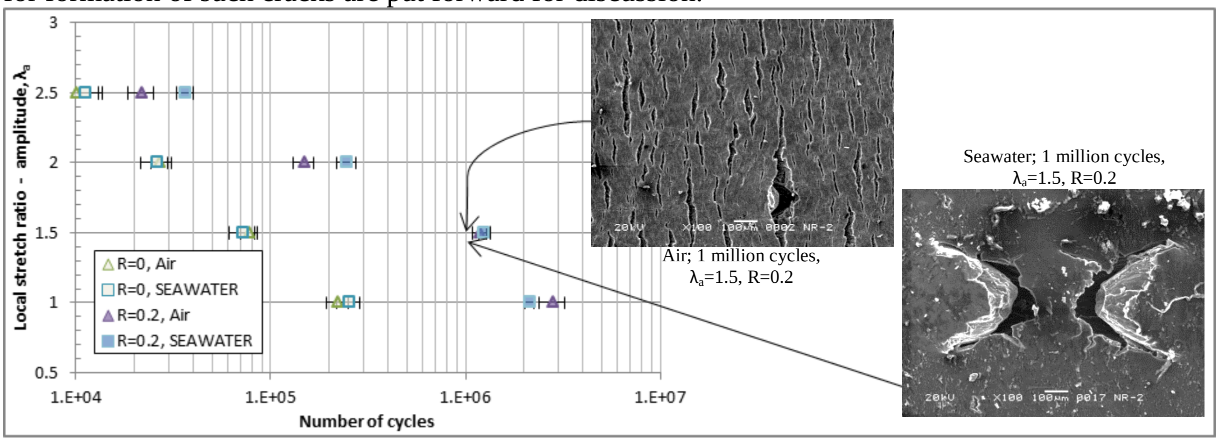

Figure 1. Average fatigue life of NR in air and seawater environments at R-ratios 0 and 0.2; SEM micrographs at x100 magnification for amplitude λ_a=1.5, R=0.2, 1 million cycles.