Transition from steel wire to cable in fatigue life prediction under complex loads

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Abstract

A truck tire is a complex assembly of several composite plies composed of an elastomer matrix reinforced by steel cords. These cords consist of several thin, high-strength brass-coated steel wires assembled in a helix. Their primary function is to support the mechanical cyclic loading induced by the vehicle rolling, which leads to fatigue damage. However, during tire life, oxygen and water from the ambient environment can diffuse through the polymer matrix because its aging causes a change in its chemical properties, adding a combined corrosion effect to mechanical fatigue.
To reduce the global weight of a truck tire, the total mass of steel cords, which represents 25 % of the tire's mass, should be reduced, leading to higher stresses on the material. Still, this reduction can only be done by ensuring similar or better performances. Therefore, it is of primary importance to predict the fatigue behavior of steel cords under mechanical and chemical loadings. This study aims to develop a reliable model predicting the fatigue life of steel cords, which implies understanding fatigue and fatigue-corrosion mechanisms. Considering a multiscale approach, a pre-existing lifetime prediction model at the scale of a single wire (1) has been enriched to consider the fatigue-corrosion mechanism of brass-coated steel wires, which is caused by a double galvanic coupling: dealloying of the brass and, due to a not fully covering coating, preferential corrosion of iron (2). This damage of fatigue corrosion was studied using an experimental setup that enabled electrochemical measurements to be carried out during a bending rotation test.

A lifetime prediction model at the scale of the steel cords was developed based on this single wire model. Stress states in each wire were obtained using finite element simulations of a cable surrounded with a rubber matrix and subjected to bending and tension-bending loadings. The damage of these wires was first considered independent from one another, and their fatigue lives were computed using the single wire model, enabling the computation of a probability of rupture. The lifetime results were compared to experimental fatigue lives of cables subjected to bending-tension cyclic loadings.

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