Abstract

Fiber reinforced elastomeric composite materials have unique characteristics and are becoming more and more popular in different industrial applications. However, the prediction of the mechanical behavior of such materials is essential and complicated. The nonlinear load-extension response of the incompressible, or nearly-incompressible elastomeric matrix and its viscoelastic nature create that complication in its behavior. Another complexity is added when reinforcing fibers are introduced within the matrix. This complex behavior of fiber reinforced elastomeric composites needs more understanding, and requires extensive experimental and theoretical works in order to attain a simple and an applicable constitutive model. Experimental investigations of the present work involved both, the fabrication of tests' specimens and their testing. The standard pure-rubber and fiber-rubber dumbbell specimens were fabricated and tested according to ASTM D412 specifications. The experimental tests focused mainly on performing tensile tests and relaxation tests on the fabricated specimens. Tensile tests were carried out under different strain rates in order to capture the effect of increasing the strain rate on mechanical behavior of the specimens. The relaxation tests were performed under constant strain rates and for different strains in order to investigate the viscoelastic and time-dependent properties. Furthermore, an inflated air-spring membrane was manufactured as an application of fiber-reinforced elastomeric composite in order to be used in a test rig to verify the proposed model. Theoretical works are considered for both modeling and numerical investigations. In

modeling, an anisotropic-based hyperelastic constitutive model which can be applied to numerical simulation for the response of various industrial applications is proposed. The proposed model is composed of an isotropic part, which is related to the elastomeric matrix, and an anisotropic part, which is assumed to relate to the fibers only. Two material parameters are used to describe the matrix material using a polynomial form of strain energy function (Yeoh model), while an exponential form of the strain energy function with two material parameters are used for each layer of fibers. The viscoelastic behavior is modeled by using Prony series. It is assumed that the mechanical response is decomposed into two networks: an equilibrium network corresponding to the state that is approached in quasi-static monotonic stress; and a second network capturing the non-linear rate dependent deviation from the equilibrium state. Numerical analyses were implemented in the finite element method, using ANSYS 15.0. The validity and accuracy of the proposed model have been studied. The proposed model gave a good agreement as compared with the experimental results of the present work and exhibited a good capability to predict the mechanical behavior of the fiber-reinforced elastomeric composites.