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Volume growth during uniaxial tension of particle-filled elastomers at various temperatures – Experiments and modelling

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Abstract

A common presumption for elastomeric material behaviour is incompressibility, however, the inclusion of filler particles might give rise to matrix-particle decohesion and subsequent volume growth. In this article, the volumetric deformation accompanying uniaxial tension of particle-filled elastomeric materials at low temperatures is studied. An experimental set-up enabling full-field deformation measurements is outlined and novel data are reported on the significant volume growth accompanying uniaxial tension of two HNBR and one FKM compounds at temperatures of −18, 0, and 23 °C. The volumetric deformation was found to increase with reduced temperature for all compounds. To explain the observed dilatation, in situ scanning electron microscopy was used to inspect matrix-particle debonding occurring at the surface of the materials. A new constitutive model, combining the Bergström-Boyce visco-hyperelastic formulation with a Gurson flow potential function is outlined to account for the observed debonding effects in a numerical framework. The proposed model is shown to provide a good correspondence to the experimental data, including the volumetric response, for the tested FKM compound at all temperature levels.

Keywords: Elastomers, DIC, Volumetric deformation, Low temperatures, SEM, Matrix-particle debonding, Constitutive modelling

1. Introduction

Particle-filled elastomeric materials are applied in a range of industries (like automotive, aerospace, and oil and gas) where large temperature variations can occur. As a specific example, elastomeric seals can be exposed to a wide range of pressures and temperatures in subsea oil and gas equipment. As these seals are critical to avoid leakages, strict qualification testing, possibly involving temperatures from −18 to 150 °C and pressures up to 140 MPa [1], must be carried out prior to installation. The lead-time and man-hour cost of obtaining a combination of elastomeric material and seal design that would pass the qualification tests could be greatly reduced by introducing numerical analyses, like finite element simulations, into the design process. For such analyses to be

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