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A thermodynamically consistent compressible rate-type viscoelastic model with independent limits on dilation, contraction, and distortion. Part A: Modeling

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Abstract

Carbon black filled natural and synthetic rubbers used in automobile tires have to sustain a very large hydrostatic tensile stress between the two steel belts, especially near the belt edge. In addition, the rate effect of the volumetric and the distortional response of filled elastomers becomes significant for vehicles running at high speeds. In other words, by limiting the volumetric and distortional response and making it rate dependent, one can emulate the high stresses observed in tires. There are a number of constitutive equations of the rate and integral type for filled elastomers, but none of the available models employ a rate-dependent dilatational limit. In this paper, we propose a new non-linear rate-type compressible viscoelastic incorporating individual limits for dilatation, contraction, and distortion. The rate type thermodynamic framework of Rajagopal and Srinivasa (2000) is extended to include such limits. By establishing the physical meaning of various parameters used in the constitutive equation, we show that they are tightly correlated with the certain type of experiments and can be determined from the available data in the literature. Only a few parameters need to be determined by curve fitting. The proposed model is validated using in-house as well as the other experimental data available in the literature.

In Part B of the paper, extensive validation of the proposed constitutive equation for

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