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ENERGY-MOMENTUM TIME INTEGRATIONS OF A NON-ISOTHERMAL TWO-PHASE DISSIPATION MODEL FOR FIBER-REINFORCED MATERIALS BASED ON A VIRTUAL POWER PRINCIPLE

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Abstract. Fiber-reinforced plastics (FRP) are composite materials made of an isotropic polymer matrix reinforced with organic or inorganic fibers. These materials become more and more important in order to provide light-weight structures. The major contribution to the internal dissipation in FRP is due to the isotropic matrix material. However, internal dissipation in the fibers has to be taken into account if Carbon or Kevlar fibers, respectively, are applied. Therefore, we introduce in this presentation a new two-phase dissipation model at finite strains with viscoelastic behaviour in the matrix and the fibers.

This model is based on the multiplicative split of the deformation gradient $\boldsymbol{F} := \boldsymbol{F}_{\mathrm{e}}\boldsymbol{F}_{\mathrm{v}}$ of the composite in an elastic and viscous deformation gradient $\boldsymbol{F}_{\mathrm{e}}$ and $\boldsymbol{F}_{\mathrm{v}}$, respectively, as well as on the multiplicative split of the fiber deformation gradient $\boldsymbol{F}_{\mathrm{F}} := \boldsymbol{F}_{\mathrm{F_e}}\boldsymbol{F}_{\mathrm{F_v}}$ in an elastic and viscous fiber deformation gradient $\boldsymbol{F}_{\mathrm{F_e}}$ and $\boldsymbol{F}_{\mathrm{F_v}}$, respectively. However, the time-dependent matrix behaviour depends directly on the principal invariants of the symmetric elastic right Cauchy-Green tensor $\boldsymbol{C}_{\mathrm{e}} := (\boldsymbol{F}_{\mathrm{e}})^T\boldsymbol{F}_{\mathrm{e}}$. Analogously, the trace of the elastic fiber right Cauchy-Green tensor $\boldsymbol{C}_{\mathrm{F_e}} := (\boldsymbol{F}_{\mathrm{F_e}})^T\boldsymbol{F}_{\mathrm{F_e}}$ determines the time evolution of the viscous fiber deformation.

We consider free energy functions $\Psi_{\mathrm{M}}^{\mathrm{vis}}$ and $\Psi_{\mathrm{F}}^{\mathrm{vis}}$, depending on these matrix and fiber invariants, in the virtual internal power of a mixed principle of virtual power. In the virtual external power, the non-negative internal dissipation with respect to a positive-definite viscosity tensor or a positive fiber viscosity parameter, respectively, is introduced. In this way, we derive the viscous evolution equations by a variation. The virtual internal power also includes mixed fields for the thermo-elastic matrix and fiber behaviour. Algorithmic terms in the virtual external power lead to an energy-momentum scheme, which provide energy-momentum time integrations of this two-phase model.