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ON SIMULATING SKELETAL MUSCLE FATIGUE. A 3D ELECTRO-MECHANICAL CONTINUUM MODEL.

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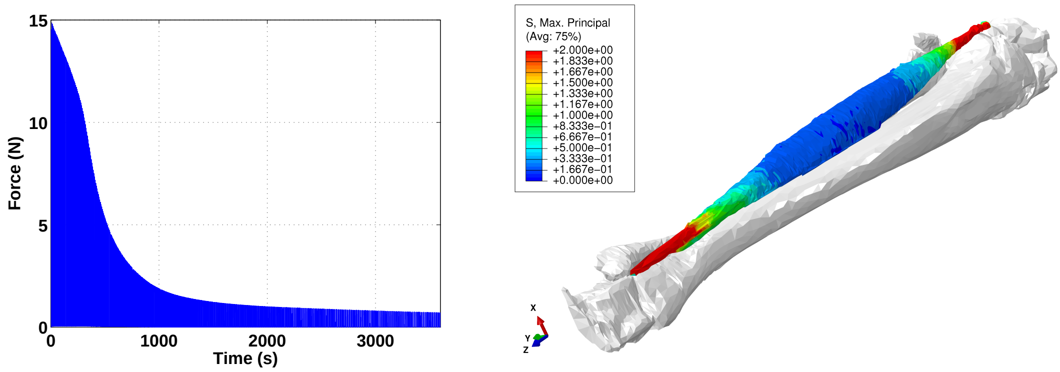
Prolonged or repeated contractions of skeletal muscles lead to a decline in performance known as muscle fatigue. In this work, a thermodynamically consistent model in three dimensions incorporating the electro-mechanical coupling is proposed for simulating skeletal muscle under fatigue conditions.

Active and passive responses are accounted for by means of a decoupled strain energy function into passive and active contributions. The active stress is obtained as the maximum tetanic stress penalized by three functions that consider the external stimulus frequency, the overlap between actin and myosin filaments and the fatigue effect. Passive response is modeled by a transversely isotropic strain energy function. The deocupled form of the strain energy function can be written as:

$$\Psi = \Psi_{\mathrm{vol}}(J) + \bar{\Psi}_p(\bar{\mathbf{C}}, \mathbf{N}) + \bar{\Psi}_a(\bar{\mathbf{C}}_e, \bar{\lambda}_a, \mathbf{M}) \tag{1}$$

where $\bar{\Psi}_p$ and $\bar{\Psi}_a$ are the passive and active contribution, respectively. $\bar{\mathbf{C}}$ is the modified Cauchy-Green tensor associated to the passive contribution of the collagen fibres with directions defined by the structural tensor $\mathbf{N} = \mathbf{n}_0 \otimes \mathbf{n}_0$. For the muscle fibers $\bar{\mathbf{C}}_e$ is associated to the directions $\mathbf{M} = \mathbf{m}_0 \otimes \mathbf{m}_0$. $\bar{\lambda}_a$ represents the active contraction.

The robustness of the model is analyzed by means of finite element simulations that reproduce the isometric contractions in a three-dimensional model of a muscle. The finite element model was obtained from computed tomography imaging and the preferential



(a) (b)

Figure 1: (a) Force evolution of rabbit *extensor digitorum longus* muscle. A 200 millisecond pulse stimulus was applied at 1/6 Hz during 3600 s. (b) Maximum principal stress distribution in the *extensor digitorum longus* model during an isometric contraction.

directions associated with the collagen and muscular fibers were considered. The proposed model was able to reproduce the observed experimental response of the active force generated by the isolated rabbit *extensor digitorum longus* (e.d.l) muscle.

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