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Enhanced Hill-Type Model for muscle contraction simulation

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ABSTRACT

The role of muscle activation on injury mitigation during high impact accidents is still debated. To accurately describe the behavior of muscle contraction during high-dynamic impacts, classic Hill models are no longer adequate. Recent studies emphasized the need to decouple the muscle fiber contractile unit's dynamics from the tendon's elastic behavior to prevent numerical instabilities during high-frequency oscillations. Consequently, an Enhanced Hill Type Model (EHTM) was developed, comprising two distinct contraction units to better model stress absorption by the tendons and a built-in neural controller that triggers muscle contraction based on muscle spindle reflex and monosynaptic stretch reflex. This study aims to translate the open-source LSDYNA® code of the EHTM to OpenRadioss® and validate its behavior at the muscle fiber level.

The validation dataset of the EHTM model was derived from an experiment on a piglet calf. The tibia was fixed, and the sciatic nerve was electrically stimulated to induce concentric muscle contraction, lifting masses of 100, 400, 800 and 1800g. An encoder recorded the axial velocity of the mass during contraction. In the simulation, the EHTM property were assigned to a spring element in HyperMesh®, embedded at one end and subjected to the same successive experimental loads. The axial velocity of the loading node was then recorded.

The model showed good agreement with experimental kinematic data. Despite a pronounced attenuation of the second experimental contraction peak for 400g and 800g masses, the ETHM's spring property accurately modeled the kinematic contraction of the piglet calf for the first loading masses (100, 400 and 800g). However, over 800g, the model failed to sufficiently damp the contraction speed. To address the discrepancies, a desirability study should be carried out on the damping parameters. The next step of this study will focus on implementing this property in a set of neck muscles to characterize the impact of muscle activation on the risk of spinal cord injury.