Active Muscles for the Implementation in Human Body Models - work in progress

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I. INTRODUCTION

Automotive safety systems are becoming increasingly important due to higher traffic volumes and increasing demands for such systems. At the same time digital models of humans serving to develop and test automotive safety systems have to satisfy higher demands in biofidelity and applicability within the digital production process. Therefore, not only forces acting on the body during the crash phase, but also the body position and forces acting in the phase shortly before the crash phase, the so-called pre-crash phase, have to be evaluated [1]. Although available models are well validated and already widely established for crash phase simulations, they lack the ability to capture the versatility of humans when dealing with different environmental conditions, such as different acceleration amplitudes or event timing [2]. In humans, skeletal muscles (pre-)set the mechanical characteristics of the joints and drive the segments to produce movement [3]. Thus, to increase biofidelity, active human body models should include an appropriate representation of the biological muscles.

II. METHODS

A classical Hill-type approach to model biological muscle was used. The novelty of this approach is the integration of a standard muscle model added by an appropriate activation dynamics model within a standard software framework already used by most car manufacturers, namely LS-Dyna®. Moreover, we validated the muscle model with experimental data from literature using a comprehensive data set including different contraction modes and load cases. Additionally, the muscle model was tested with THUMS®v3.

Computational Modeling

The experimental data used for this study was already published [4]. In analogy to the referenced paper, the published data set was used to validate the simulation results, depending on the simulated condition: isometric contractions and concentric contractions with different loads. To model the Hill-type muscle with LS-Dyna® the material card MAT156 was initially used to study the influence of the different parameters. This material model was then further developed and transferred to a separate user material. The user material was enhanced by one ordinary differential equation accounting for Hatze's activation dynamics [5]. Additionally, we implemented a routing algorithm to account for redirected muscle paths when wrapping around bones or tendon sheath.

III. INITIAL FINDINGS

First simulation results show good agreement with literature data regarding time course and maximum contraction velocities for different loads in the concentric contraction condition. Additionally, a first test of the new muscle material model included in a THUMS®v3 model showed a better fit to the movement and velocity corridor found in literature [6] for a 15g high impact scenario when fully activated compared to a non-activation state. The third test of the new muscle model including the routing algorithm with a THUMS®v3 resulted in better kinematics, i.e. ducking of the neck was less pronounced (see Fig. 1).

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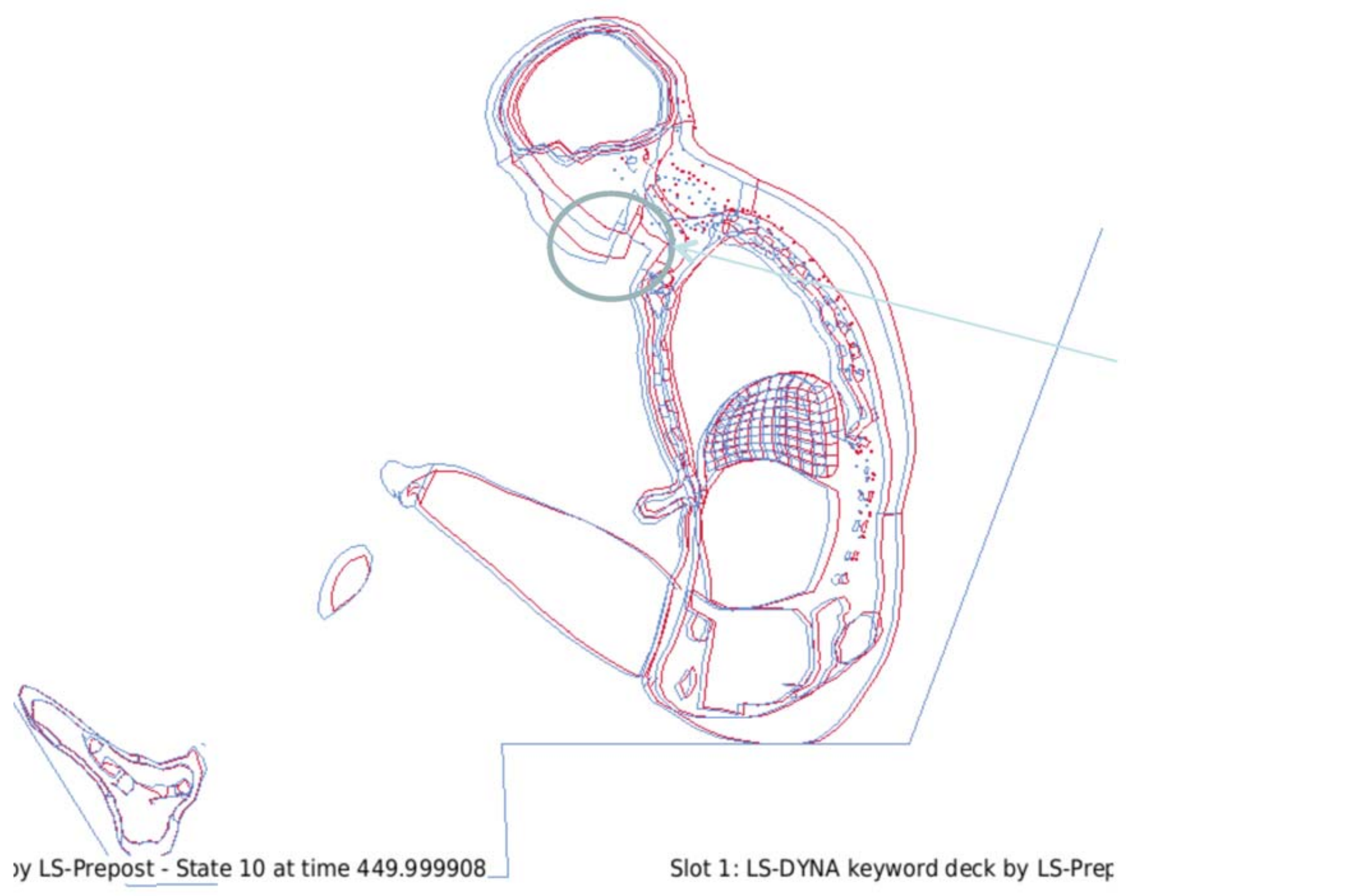

Figure 1: Simulation result of THUMS®v3. Ducking of the neck was reduced using routed muscle paths. Red solid lines depict start and end position for the routed case, blue solid lines depict the non-routed, straight line muscle approach. The arrow highlights the chin area, were the differences are most obvious.

IV. DISCUSSION

This short communication reports on work in progress. The goal of the project is to proof the concept of using a standard macroscopic muscle model including physiologically valid activation dynamics integrated in a commercially available software package and human body model. This model fusion is beneficial in several ways. First, the industrial workflow can remain as established using all tools and models already available. Second, when using biologically valid muscle models, the parameterization of the muscles used can easily be taken from literature data. Third, biologically inspired motor control can be integrated in a yet simple but valid manner, by using established motor control models. A recently published closed-loop control model [7], could be one example for that. Although musculo-skeletal human body models for studying automotive safety have a long tradition, e.g. [8], recently published work give a new push towards active human body models including muscles [9]. Future work in the study presented here, will focus on the integration of multiple muscles in a human body model. Additionally, muscle routing will be integrated for all muscles and evaluated thoroughly to account for valid, deflected muscle paths.

V. REFERENCES

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