GAIT SPECIFIC OPTIMIZATION OF ATHLETIC FOOTWEAR

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ABSTRACT – Several studies have indicated a functional relationship between footwear and strike patters in runners (Kasmer et al. 2016). The mechanisms that dictate these kinematic adaptations, are widely accepted to rely on the way impacts are sensed and transferred through the runners' musculoskeletal system (Lieberman et al. 2010). As a result, multiple midsole technologies have been introduced over the past years, in an attempt to accommodate the needs of elite and habitual runners.

Despite however the significant efforts dedicated to decipher both, running biomechanics and impact mitigation, it is still poorly understood how foot placement affects the cushioning capacity of specific midsole systems. The objective of this study, was to demonstrate the effectiveness of Finite Element (FE) modelling techniques, in optimizing a midsole system as to the provided cushioning capacity.

A commercial running shoe was scanned by means of micro Computed Tomography and its gel-based midsole, reverse-engineered to a 200μm accuracy. The resulting 3D model was subjected to bio-realistic loading and boundary conditions, in terms of time varying plantar pressure distribution and shoe-ground contact constraints.

The mesh grid of the FE model was verified as to its conceptual soundness and validated against velocity driven impact tests (Tsouknidas et al. 2017). Non-linear material properties were assigned to all entities and the model subjected to a dynamic FE analysis. Folowing this, an optimization function (based on energy absorption criteria) was employed to determine the optimum gel volume and position, as to accommodate sequential cushioning in the rear-, mid- and forefoot, of runner during stance phase.

The max. von Mises stress, developing on the midsole was in the range of 6,2 MPa (prior to optimization), observed during impact peak (around 0.09ms of stance phase) on the lateral side of the foot, in-between the calcaneus and the cuboid. This coincides well with the timing of the max. plantar pressure, while stressing the significant force dissipation throughout the midsole structure.

In an effort to avoid violations of a stability constraint, our optimization function proved less sensitive to design variables than expected. It would thus be preferable to focus on the constraint-handling method e.g. a Pareto based concept (Oyama et al. 2007) examining the degree of violation, rather than a non-violating criteria approach.

Despite this, the in-situ developing stress fields suggest that the shock dissipating properties of the midsole could be significantly improved. Altering the position of the gel pads and varying their volume, led to different midsole responses that could be tuned more efficiently to the specific strike and pronation pattern.

Figure 1 highlights changes in the stress concentrations observed in both, the gel pad and the EVA foam. Despite the similarities in the developing stress fields and the trends observed, transition of peak stress from gel in the heel-pad region (figure 1a) to the one placed under the central forefoot (figure 1b), the developing stress patterns were clustered slightly differently while exhibiting max. values up to 9% apart. The higher stress range in the optimized gel-pad configuration, indicates the higher strain energy absorbed in this scenario.

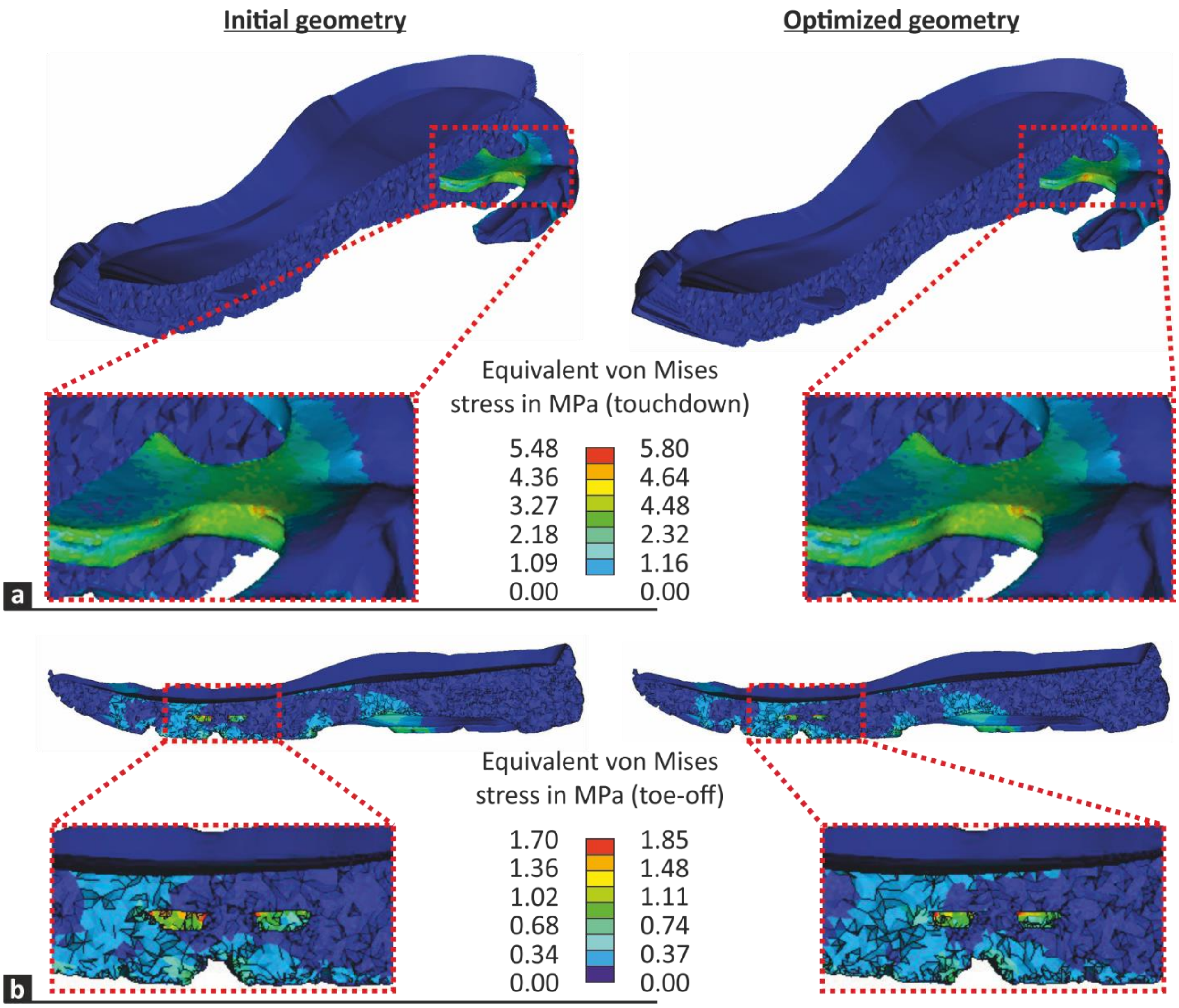

Figure 1 – Varying stress distributions in the initial vs. optimized gel-pad configuration, during: a) touchdown and b) toe-off.

The results confirmed the hypothesis of the study, suggesting that midsole design could be significantly improved through the use of bio-realistic FE modelling techniques and proper optimization functions, providing a new platform for the conceptual re-design and/or optimization of modern footwear.

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