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Development of a methodological framework linking the properties of complex materials to the mechanical reaction of functional insoles used in podiatry : Project Podomat

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Introduction

The design of podiatric insole aims at reducing the maximal pressure under some regions of the foot, especially in the case of diabetic patients. Despite the current evolution of the computer-assisted design, the choice of the materials and their geometries (cut shape, thicknesses) are still empirical, according to the experience of the podiatrist.

Objectives

The Podomat project started to optimize this practice using a coherent database of materials and the adequate material laws to be used for mechanical simulation and for the material and design selection in podiatry. To achieve this, three tasks are set to interact with each other.

Approach : 3 activities

- Characterization of foam material properties by tensile-compressive test. This study provides essential nonlinear characteristics needed for mechanical simulation in addition to the information given from the supplier such as Hardness and Density.
- Numerical simulation to predict pressure distribution under foot. This study is confirmation of combined physics of materials and insole design approach.
- Planter pressure measurement for understanding of interaction between the foot and insole material and geometry. The result will be an essential data for confirmation of characterization procedure and simulation. The insole design parameters (material, inclusion) should be studied.

Conclusion and perspectives

The framework of study is established for static condition using limited number of measurement of materials and simulation usint their characteristics. The flexible pressure measurement device is calibrated, and insole design tool is ready.

For the future, we will improve its quality by increasing case number (more materials, sample number, combined effect of material and geometry, demonstration by simulation and by measurement) and completing database. We are planning to introduce the same approach in dynamic condition (material viscoelastic properties dynamic pressure measurement and simulation.

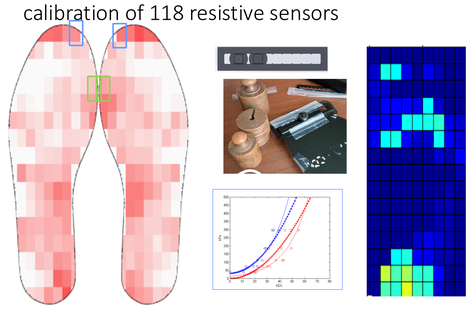
2: Biomechanical measurement and insole design

Baropodometric pressure measurement

Ⓡ WINPOD WIFI of Medicapteur [3]

Measurement of planter pressure

calibration of 118 resistive sensors



Perspective:

Measurement of planter pressure, pressure under insole

Insole design solution

Correction by orthopedic insole based on footprint and podiatric analysis

Multiple adaptation

Material change

Removing a material and addition of another one.

Perspectives

Determine the best material for each condition of use: Materials type and thickness.

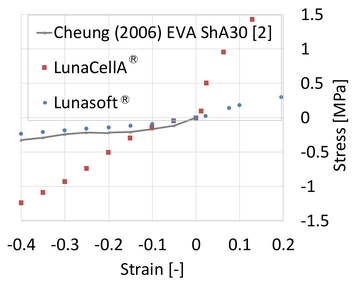
Material choice ⇄ Input for material test condition coherent to insole

Boundary condition (Pressure to apply) Geometry of insole ⇄ Pressure distribution under different insole Confirmed physical criteria for design

1: Material characterization

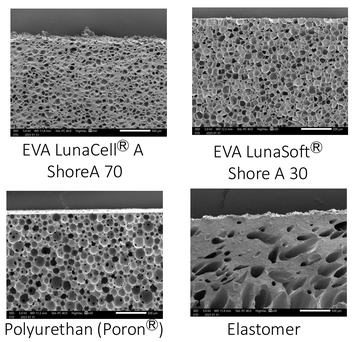
Tensile and compressive test :

Ethylene-Vinyl Acetate copolymer (EVA)



Microstructure observation:

Scanning Electronic Microscope (SEM). (Open/semi-closed)



EVA LunaCell® A ShoreA 70

EVA LunaSoft® Shore A 30

Polyurethan (Poron®)

Elastomer

Perspective

- Complete measurement for material database: EVA (45-65 Sh), Polyurethan, Elastomer.
- Quality improvement (sample number, better resolution of displacement, load cell resolution)
- Further mechanical properties (Poisson. coefficient, dynamic proprieties)

Method Condition ⇄ material law

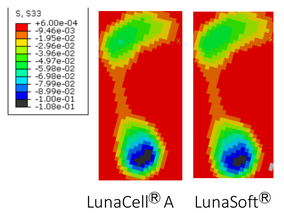
3: Finite Element Method (FEM)

Static nonlinear calculation is realized using experimental data (material characteristics and planter pressures).

On flat insole (4mm)

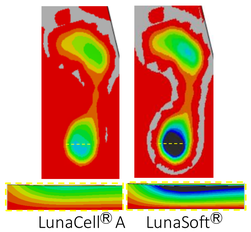
Small variation of pressure under insole

Pressure under flat insole



LunaCell® A LunaSoft®

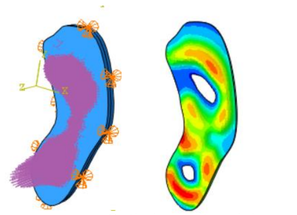
Top displacement (surface)



LunaCell® A LunaSoft®

Geometrical optimization

Searching a design to attenuate max. Von Mises



Initial insole

Optimized with minimum of max V.M.

Perspective

- Validation of numerical method by more experimental results. Confirmation of influential parameters.
- Combination of material with a real insole geometry.
- Identification for physical criteria for numerical solution (deformation energy, hydrostatic pressure) confirmed with podiatric design.

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