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# Assessment of mechanical tests to characterize 3D kinematic behavior of running sport shoes.

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**Abstract** —The main purpose of this study is to determine which mechanical solicitation acts on the upper part of shoes during sport movements. Nine trained runners performed walk, run and countermovement jumps with 5 different pairs of running shoes. Strain fields in the upper part were measured using stereo Digital Image Correlation (DIC). An analysis of those results from Strainmaster_Davis yields to observe shear and compression strain components. The results of those acquirements will allow the development of specific characterization tests on coupons to measure textile materials performance in order to improve durability of shoes.

**Keywords** — DIC, Photomechanics, shoe upper, textile, strain, running shoes.

## Introduction

A lot of research about sport shoes has been taken to study the sole mechanical behavior [1] in order to provide the best cushion system, improving grip or comfort. Although, the knowledge about foot and sole interactions is still growing, there is yet less study about foot and upper interactions. The understanding of wear phenomenon caused by sport movements repetition is the essential motivation of this project. In this purpose, stereo-DIC measurements have been carried out to characterize the real mechanical solicitations to which the shoe upper is subject. Thanks to these measurements, specific characterization tests which can be established in labs, such as described in [2], will be proposed to study the performance of textile materials under the identified spectrum loading. This work intends to be the first step for a predictive finite element modeling.

## Methods

A total of 9 non-debutant runners with a specified shoe size EU43 participated to this study. 3D Foot scan was performed for each of them using Elinvision 3D Foot Scanner. Participants were asked to consecutively walk and run on a treadmill at 4km/h and 10km/h respectively (Figure 1), and perform countermovement jump. Five running shoes of different types and variable durability where tested. Shoes were new before the beginning of experiments and all participants used the same pairs. Left shoe of each pair had been priorly prepared with speckled black and white acrylic paint on lateral side.

Figure 1: Data acquisition of a running subject

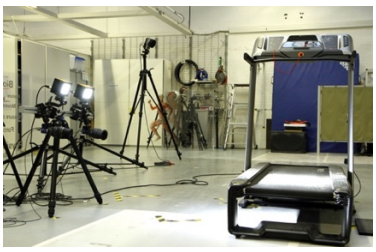

Figure 2: Presentation of the acquisition set-up

Stereo-DIC measurements were performed using LaVision StrainMaster Portable system with two 2 M-lite 5Mpx cameras positioned at 2m from the area of interest and separated with an angle of 20° (Figure 2). System was calibrated before treadmill and jump activities. Data was captured at 10Hz using StrainMaster DIC Software. After recording, a first strain analysis was performed with a subset size of 19 pixels and a step size of 6 pixels. Strain fields of the shoe upper surface are displayed (Figure 3).

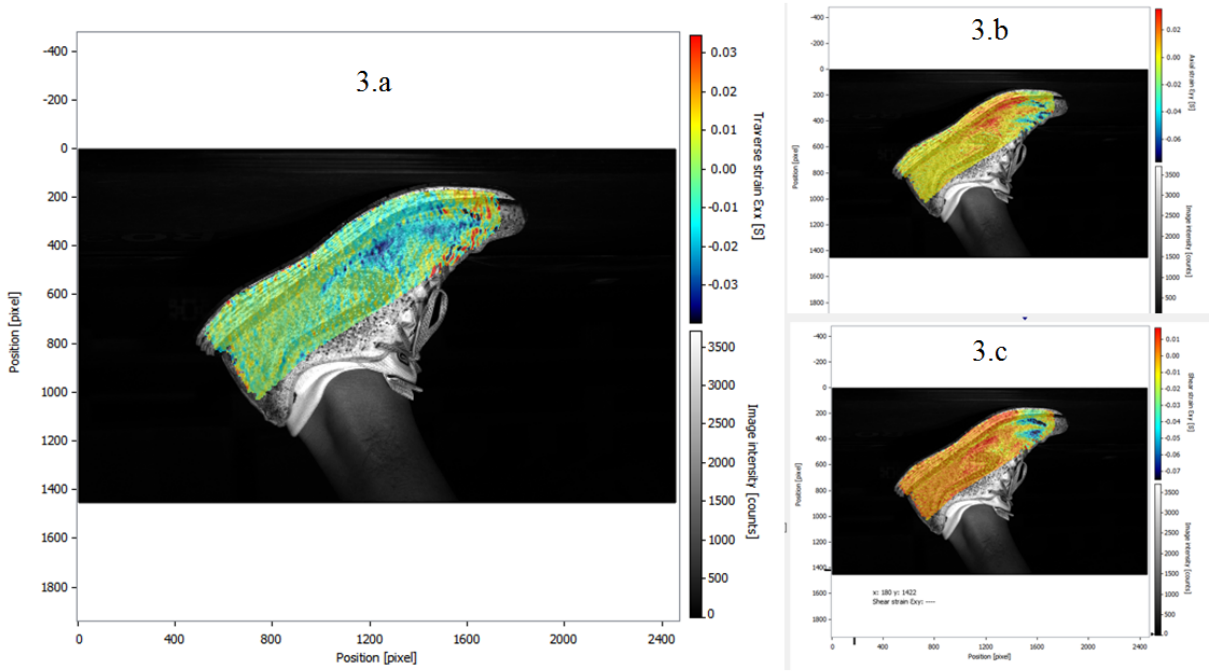


Figure 3: Maps of the first transverse (a), axial (b) and shear (c) strain analysis.

**Results**

Figure 3 presents an overview of the results obtained with such method. These pictures seem to introduce specific strain phenomenon in the foot flexion zone as mentioned in [3]. These deformations, which differ from the other part of the shoes, show the impact of foot-upper interaction on mechanical solicitation.

**Discussion and Conclusion**

The strain analysis from the acquisition of the 9 runners allows observation of strain field in several critical parts of the upper shoes especially on the vamp. These measurements suggest that shoe upper is subject to specific strain field and type during the studied use cases, that stereo-DIC helps to identify. The purpose of this project is to improve durability of shoes by developing specific tests to characterize performance of materials. The next step of our work is a test campaign on coupons of the textile materials from the tested shoes in order to meet two objectives. On the one hand, to provide new design criteria for shoes and on the other hand to permit a better knowledge of the mechanical constitutive model of those materials. Raising our understanding of the mechanical behavior of textile materials should allow to develop predictive finite elements models.

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