Preliminary Study of Contact Modelling the Interface between User Skin and Wearable Equipment

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Abstract

For a suitable development of wearable equipment, it is important to take in consideration comfort issues, and the simulation of the contact between is the adequate tool. To simulate the contact a preliminary study an empirical models were developed using non-linear fitting. The data was collected using compression and decompression tests using different indenter's diameters in one subject.

Key words: wearable equipment; compression test; soft tissue deformation; comfort; non-linear estimation

1 Introduction

The main issue in design of wearable equipment is the comfort of the user [2]. For development of these products is essential to model the contact between user and equipment [5]. Therefore, mathematical models are needed in order to simulate the force transition at skin level. Since the information for skin properties is sparse and dispersed, as described in 2012 by Silva et all [4], one of the problems faced is the choice of parameters and equations used to calculate the forces and the correspondent deformation. Theoretical models and empirical models can be developed. The present study is an attempt of establish an empirical model between forces and deformation using nonlinear regression [3].

2 Experimental methods

In order to define the empirical equations between the force and the deformation of tissues, "in vivo" compression tests were performed using a soft tissues (user skin) testing equipment developed for the purpose, which allows analysing the force and deformation during the test. Tests were made on the left anterior part of the leg in a 22 years old female subject with the body mass index (BMI) of 22.8. The leg was supported during the tests so that no muscular activation was needed. Spherical stainless steel indenters with four different diameters were used: 5, 10, 15 and 20 mm. Forces were applied perpendicular to the leg surface. The indenter approaches the skin surface and initiates the indentation at a velocity of 1 mm/min. When the subject feels unbearable pain a controller is actuated by the subject and the indenter returns to its original position unloading the skin. The force is measured by a force transducer (0-250N) in the indenter probe and the deformation is registered by a potentiometer transducer (0-50mm). One test was performed for each indenter in the anterior and distal part of the leg. During compression and decompression, values were collected for the deformation of skin and the correspondent applied force.

3 The model

To get our empirical models we have used the statistical toolbox of MATLAB. Several non-linear models using nonlinear regression were tested. The simpliest ones are cubic polinomial and exponential models. The models which relate the applied force and deformation of skin, were estimated considering four different diameters for the stainless steel indenters (5, 10, 15 and 20 mm).

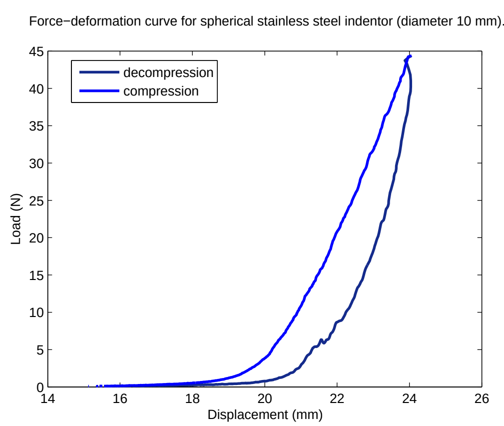

Figure 1: Force-deformation curve (indenter diameter equals 10 mm).

To ilustrate our work, we consider the case when the diameter of indenter equals 10 mm and 20 mm. The empirical force-deformation curve (diameter 10 mm) is displayed on figure (1). In figure (1) we distinguish two distinct parts: the compression curve (top) and the decompression curve (bottom). Each separate part, compression (top) and decompression (bottom) respectively, are modelled separatelly.

The empirical models obtained when indenter diameter equals to 10 mm and 20 mm are presented in figures (2) and (3) respectivelly. In both figures, the graphics on left represent the models obtained using cubic polynomial functions. When we use exponential functions, the empirical model is less competitive when indenter diameter is 10 mm (see on the right of figure (2)). For some other cases of study, the exponential fitting reveals to be the proper choise. When we consider the case with diameter equals to 20 mm, presented in figure (3)), both models obtained by exponential fitting and cubic polynomial fitting have good adjustments and equivalent performances. Another models, using different nonlinear functions, were considered reproducing properly good estimates. All selected models reveal correctly the physical interpretation of the coeficients (such as the viscosity).

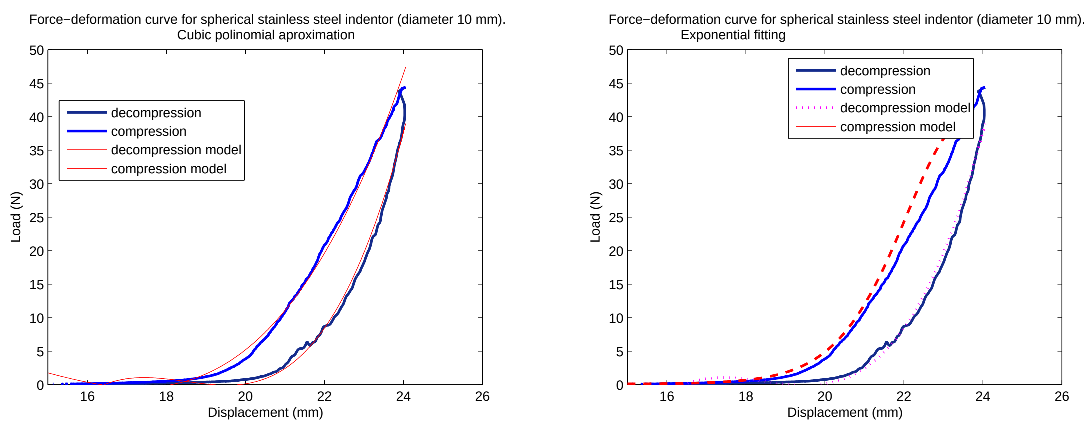

Figure 2: Force-deformation model using polinomial (left) and exponential (right) fitting (indenter diameter equals 10 mm).

4 Conclusions and ongoing work

This is a preliminary study. In the future it will be developed a theoretical model on base of the viscoelastic properties of polymeric materials. The estimated models are in agreement with [1], where Pons concluded that soft tissues of the forearm could be modelled by a third degree polynomial which relates the applied force and the deformation of tissues. We have

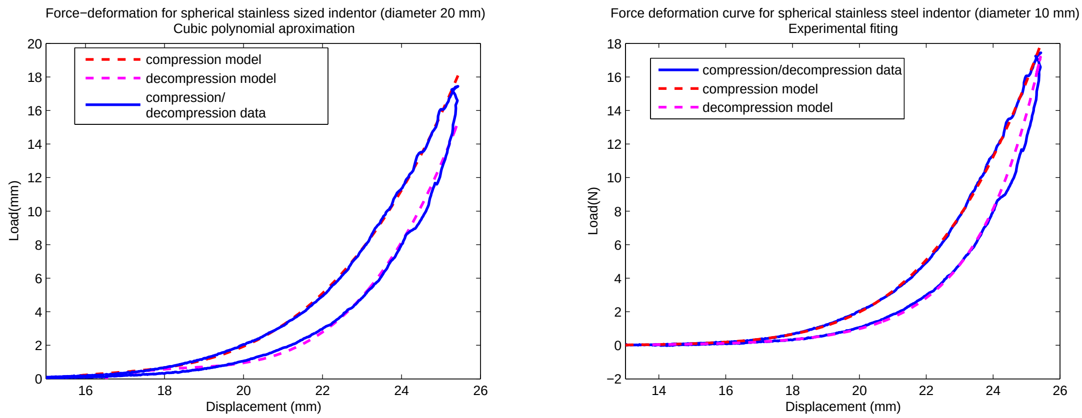

Figure 3: Force-deformation model using polinomial (left) and exponential (right) fitting (indenter diameter equals 20 mm).

good expectations about the ongoing work. The empirical exponential models obtained are being related with theory. Once we are updating all data and introducing some new variables, we are also improving our empirical models. Notice that we have considered a particular case where a specific application was modelled, but some issues can be extended and used for wearable robots.

References

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