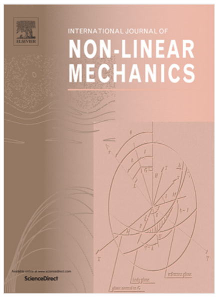

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Large Deformation Mechanics of a Soft Elastomeric Layer Compressed by a Finite Flat Rigid Punch for Tactile Sensor Applications

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Abstract

In this study, we develop a large deformation analytical-empirical model for a flat finite punch pinching on an incompressible, polymeric layer under plane strain conditions. The model could further advance the predictive capabilities of enhanced tactile sensor response models. The aforementioned model is developed based on the analytical model for an infinitely long layer under uniform compression which has been presented in [1]. Related non-linear finite element (FE) simulations with large strain, large deformation assumptions are carried out in this study. Using the FE finite flat punch simulations, the uniform layer compression model is properly adjusted to predicting the finite punch layer response. The mechanics of the polymeric layer in the vicinity of the symmetry plane, under the application of a flat finite rigid punch is fully analyzed and an expression for the indentation force as a function of the applied top surface deformation is developed. The relevance of this result to modeling the non-linear tactile sensor response over a broad sensing range is discussed. The reported results are compared to FE simulations for applied surface deformation levels of up to 40 percent of the layer initial thickness, and punch half-length to layer thickness ratios of 1 to 2. Great agreement is found to exist between the analytical-empirical model and the FE simulations. For completeness, this new semi-analytical model is fully summarized in the Appendix of this work.

Keywords: Finite flat punch indentation, hyperelastic material model, large deformations, non-linear analytical-empirical model, non-linear finite elements, tactile sensor modeling.

1. Introduction

Rubber like and polymeric materials received increased interest over the last few decades primarily due to their applications in food, pharmaceutical, biomedical and military. Polydimethylsiloxane(PDMS) is a polymer based material which exhibits similar behavior as rubber [2]. Due to its unique characteristics, such as flexibility and conformability [3, 4], PDMS has been largely used as a substrate of flexible microelectromechanical system (MEMS) tactile sensors in the past decade. Understanding the response of these materials under large deformation conditions can provide invaluable information regarding the design and selection of suitable materials for different applications.

In previous work [1], an analytical model capable of predicting the non-linear response of a polymeric layer under large deformation due to the top surface compression was developed. The aforementioned model was then used to predict the response of a MEMS tactile sensor under compressive force [5]. In doing so, an initially infinitely long polymeric layer was assumed uniformly compressed at its top surface, simulating an infinite layer-infinite punch condition. As discussed in details in [1, 5], such an assumption causes unrealistically high pressures in the sensor electrode gap region, which in turn, makes the required contact force estimates unrealistic.

An improvement to the tactile sensor model developed in [1, 5] is to use an infinite layer-finite punch assumption which, as will be shown, can be formulated as an indentation problem. More specifically, the improved tactile sensor model can be formulated as an indentation of a homogeneous, incompressible, isotropic half-space deformed by the action of a rigid, flat punch pressed normal to the plane boundary.

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