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Design of auxetic damper for lower limb prosthesis

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Abstract: Performing everyday activities can be a challenge for amputees. The usage of inappropriate prosthetic devices may cause patients to be unable to provide the foot stable ground contact. This can result in a loss of stability. Due to this fact, dampers are added to the prosthetic appliances to assist amputees' walking locomotion. They have a significant impact on the transfer of vertical ground reaction force to the lower limb joints. To increase the effectiveness of the dampers, the use of auxetic materials in their construction has been proposed. These materials, with a negative value of Poisson's ratio, could be characterized by some enhanced mechanical properties like higher vibration or energy absorption. In this study, different auxetic cells were compared in terms of damping properties. The aim of this research was to proposed new application of auxetic materials in lower limb prosthetics. First, the geometry of the damper was proposed. The auxetic damper model was numerically tested for various gaits phases. The parametric study was conducted to determine optimal shape and geometrical characteristics of the auxetic structure for this purpose.

Keywords: auxetics, dampers, prosthesis, negative Poisson's ratio

1. Introduction

The phenomenon of damping is an important aspect to consider during designing lower limb prostheses. The application of inappropriate prosthetic devices may cause patients to be unable to provide the foot stable ground contact which can result in a loss of stability [1]. In prostheses, which structure does not have adequate damping properties, additional dampers should be included [2].

Materials, which possess a negative Poisson's ratio are called auxetic metamaterials [3]. This property results in unintuitive behavior — when auxetics are stretched in one direction, their structures undergo expansion in the transverse direction. During compression, the auxetic materials contract [3,4]. These materials are characterized by unique properties such as high energy absorption or indentation resistance [4]. In the study described in [5], the energy absorption capacities of auxetic re-entrant cells and non-auxetic honeycomb structures were compared. The re-entrant structure provides more advantageous damping properties. The study [6] demonstrates that auxetics structures could provide low relative density and outstanding damping properties synergistically. In this study, the unique properties of auxetic structures were used in dedicated dampers for lower limb prostheses.

2. Models and methods

In the study, a damper model was created using auxetic structures. The construction was numerically tested for different gait phases. Auxetic structures, made from materials with positive Poisson's ratio, achieve unique properties like negative Poisson's ratio via cell geometry. Two auxetic struc-

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tures were investigated in the study (Fig. 1). The influence of individual geometrical features of the structures on the obtained damping properties was also investigated.

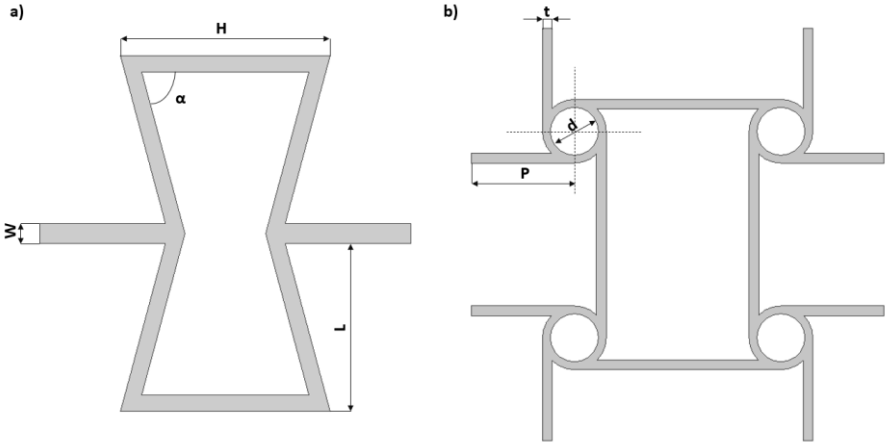

Fig. 1. Geometrical parameters of auxetic structures a) re-entrant unit cell, b) anti-tetra chiral unit cell

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