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Soft robotic prosthetic hand based on Fin Ray® effect

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Abstract

In this paper, we present the design and prototype of a soft robotics based prosthetic hand, inspired by the Fin Ray effect. The proposed device is designed for hand amputees, to gain the lost grasping capability and dexterity of an actual human hand. This is an approach to overcome the issues related to weight, wear and tear, and obtrusive appearance present in existing rigid link-based prosthetic hands. The proposed prosthetic hand is actuated through a single linear actuator. We performed a set of numerical simulations to find out the best suitable dimensions of the parameters on which the grasping capability of the Fin Ray® effect-based fingers depends. A hand prototype was made using 3D printed fingers constraining the dimensions to that of the human hand. The experiments showed that the weight lifting capacity of the prototype is around 500g before failing.

Keywords: Fin Ray®, Soft robotics, Under actuation, Conformal grasping

Introduction

Soft and adaptable manipulators in the case of bionic robots have resulted in a great reduction of control complexity by their material softness and mechanical compliance. It has the capability of achieving form closure by utilizing its compliance nature which enables the improved ability to grasp delicate objects with varying shapes. Researchers for the past few decades are working to develop underactuated robotic manipulators using soft robotic concepts. To name a few techniques, pneumatic-actuator based manipulators, shape memory alloy (SMA) based manipulators, and Fin Ray® effect-based manipulators can be listed. Out of these techniques, a pneumatic-actuator based manipulator is usually not preferable for prosthetic hand application, due to its heavyweight, high noise emission and need for air-tight parts. Furthermore, SMA based manipulators are highly sensitive to ambient temperature and are difficult to achieve repeatability. The Fin Ray® effect-based fingers for prosthetic hands provide a robust alternative with lesser weight, reduced control complexity, low noise emission, and is capable of grasping complex-shaped objects. Therefore, Fin Ray® effect-based manipulators can be an interesting and effective solution which overcomes the problems occurring in rigid link-based manipulators and other soft robotics-based manipulators, for potential application in designing a prosthetic hand.

Methodology

Fin Ray® effect-based finger is a monolithic structure with a triangular shape. One of the two ends at the base side is fixed rigidly to a structure while the other end is pulled in the direction away from the tip of the triangle. This way, if two or more fingers are positioned face to face and the movable ends of these fingers are pulled simultaneously, the fingertips of each of these fingers come closer to each other. Thus, an object placed in between these fingers can be held by these fingers.

In this work, a prosthetic hand consisting of a thumb and four fingers has been designed as shown in figure 1. Figure 1 also depicts the effect of displacing the movable end from point A to point A″, while contacting a fixed rigid object. The design parameters such as outer wall thickness, number of ribs, rib angle, the thickness of ribs, outer wall slope and finger width are adjusted to maximize the equivalent normal stress on an object while keeping the deformation to a minimum while grasping an object. The FEA simulation of the behaviour of the proposed CAD models is presented in this paper. The ideal design is then selected based on the best suited behavioural characteristics among those designs. A

prototype with the selected design parameters using Thermoplastic Polyurethane (TPU) for the finger part and Polylactic acid (PLA) for the palm and wrist part has been developed.

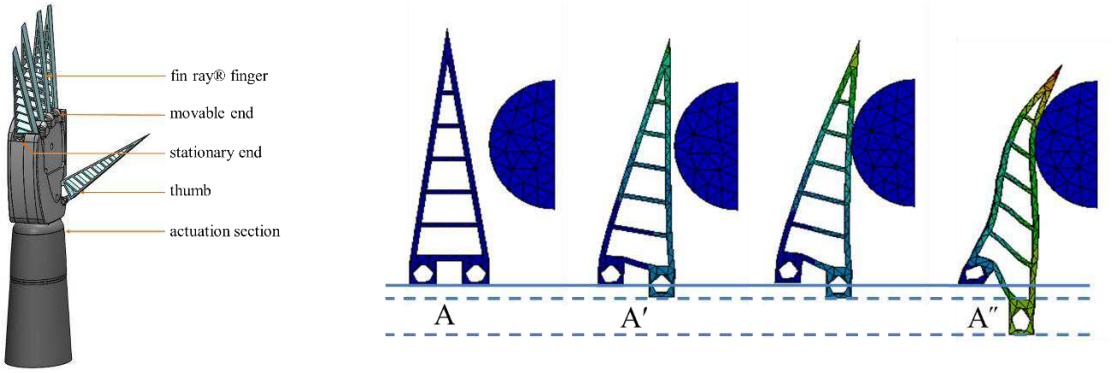

Figure 1: CAD model of the proposed prosthetic hand and graphical representation of Fin Ray® effect based finger during contact with an object.

Results and discussion

The contact stress analysis was performed to observe the resulting deformation of the fingertip. The simulation was set by placing a fixed rigid cylinder next to the finger while a stroke of 20 mm was applied to the actuated link of the finger. The resultant behaviour of a specimen of the finger is shown in figure 2.

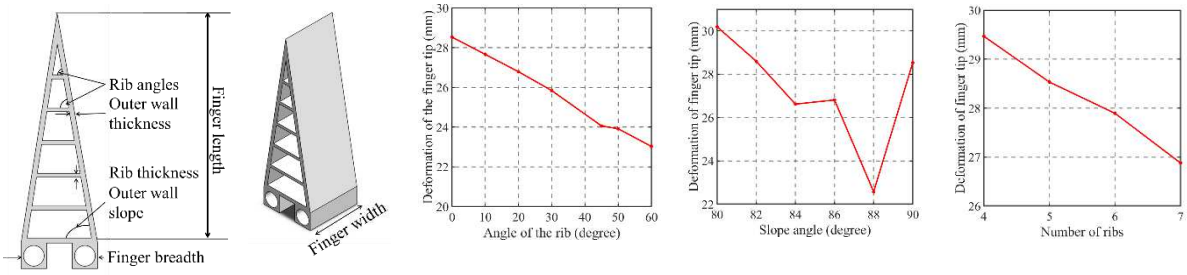

Figure 2: CAD model of Fin Ray® finger-pointing factors taken into consideration for variation and deformation of fingertip upon changing the a) angle of the rib b) slope angle c) the number of ribs.

The best suitable dimensions which result in the lowest deformation of the fingertip in each case have been selected for designing the proposed device. The 3D printed model of the proposed device has been developed. We evaluated the hand's performance in grasping various ADL objects with different shapes and sizes to observe its shape adaptability and the device grasping ability. The overall results showed that this concept can be extended to the design of a soft robotic prosthetic hand with improved grasping capability. In future, we are planning to test the device with patients suffering from upper limb amputation.

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