DESIGN AND CONSTRUCTION OF A THREE FINGERED ANTHROPOMORPHIC HAND. EXPERIMENTAL TESTS

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Abstract: This paper presents the basic aspects regarding the development of a three fingered anthropomorphic hand (structural analysis, actuation concept, fabrication of the parts), followed by the experimental testing.
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1. Introduction

Human hand is the one of the most complex, versatile, performant prehension system made by nature. The goal of any research related to anthropomorphic hands is to achieve the abilities of human hand (replicating the exact movements, their amplitudes, etc.).

The anthropomorphic hands (AH) can be found in the medical world as prosthetic devices or even in robotics as robotic hands. Because the mechanism of human hand is so complex, in both fields (robotics and medicine), simplifications are made in order to obtain a feasible model [1]. Responsible for this compromise is the difficult arrangement of mechanical components, actuators, transmissions, power sources, sensors and control systems in a compact design that has to possess the shape, size and weight close to those of the human hand.

2. Examples of Anthropomorphic Hands

A great number of anthropomorphic hands have been developed in the last decades. One of the most important accomplishments in this field is the Cyberhand (see Figure 1), developed by an international team of researches conducted by the ARTS Lab Scuola Superiore Sant’Anna, Pisa, Italy [3]. The Cyberhand has five fingers, three phalanxes per finger and independent actuation system for each finger. The degree of freedom for the mechanism of is $M = 16$ (the four fingers can perform flexion-extension movements, while the thumb can do, besides flexion-extension, the adduction-abduction movements).

Cyberhand is electronically actuated and controlled by a number of six DC motors and a great number of sensors (position, force, pressure, etc.).

![Figure 1 – The “Cyberhand”](image)

The Shadow Hand [4], [5] is considered one of the most complex anthropomorphic hands ever made. This hand is equipped with five fingers, the configuration, shape and dimensions of each finger is close to those of the human hand.
The degree of freedom of the mechanism of the hand is $M = 24$. 40 artificial muscles are used for the actuation of the fingers. These artificial muscles are nothing but pneumatic actuators. The forces developed in these artificial muscles are used to stretch the cables which in turn actuate the fingers.

The i-Limb Hand [6] is considered one of the most capable prostheses for the hand or upper limb. This anthropomorphic hand possesses five fingers, each with two phalanxes (the degree of freedom for the mechanism of the hand is $M = 11$). The actuation is made by five DC motors placed in the palm. Working as prosthetic device is enabled by two electrodes bonded to the patient skin which collect the myoelectric signals from the muscles and transmit these signals, together with the informations from the sensors, to a microprocessor.
3. Structural Synthesis

The structural synthesis can be made considering the following criteria: the number of fingers, the number of phalanxes, the relative dimension of the phalanxes, the relative position of the fingers, the degree of freedom of the mechanism of the hand and the characteristic constructive elements used [2].

The anthropomorphic hand (AH) from this paper possesses a palm and three fingers (two identical fingers and a thumb). The thumb is made from two phalanges (distal and proximal), while the other fingers have three phalanges (distal, medial and proximal). A parametric model of the hand is obtained by replacing the natural joints of the human hand with mechanical joints (here all the joints allow one single degree of freedom). The angle between thumb axis and the other fingers axis is $45^\circ$. The degree of freedom for the mechanism of the hand is $M = 8$.

![Figure 4](image)

**Figure 4** – The parametrical model of the AH, where 1 - palm; 2 – the equivalent of the metacarpal bones; 3 – phalange proximal; 4 – phalange medial; 5 - phalange distal; 6 – the joint between two phalanxes

4. Construction Design and Simulation

In order to develop the anthropomorphic hand a 3D model was made which enabled us to simulate the closing of the fingers and the correct kinematics. The model has been developed using SolidWorks software (see Figure 5 and 6):

![Figure 5](image)

**Figure 5** – The virtual model of the AH made in Solid Works software
5. Actuation of the Fingers

The actuation of the fingers can be: purely mechanical, pneumatically, hydraulically, electrical, using smart materials or hybrid [1], [2], [7].

The electric method of actuation was chosen considering the following advantages over others methods (pneumatically, hydraulically, and mechanical):
- the possibility of miniaturisation for the components, therefore a diminished gauge;
- minimal energy consumption;
- small mass;
- fast response;
- reliability.

A DC motor, powered by a 9V battery, coupled with a transmission (a reducer with two stages) generates the pulling forces that will tension the actuation wires for each finger, see Figure 7:

Figure 7 – The scheme of the actuation mechanism, where: M - DC motor; 1- pulley mounted on the DC motor shaft; 2 – transmission belt; 3- pulley mounted on the intermediary shaft 4; 5 – pinion; 6 – gear; 7 – pulleys mounted on the final shaft; 8 – fingers actuation cables.
6. Fabricating the Parts and the Hand Assembly

The parts needed to construct the hand assembly have been fabricated using rapid prototyping method at the Faculty of Mechanics, Craiova. This method enabled us to create a desired part directly from the CAD model. Figure 8 is a picture of the 3D Zcorp printer used for prototyping parts (in total 9 parts: 8 phalanxes and a palm).

![3D Zcorp printer](image)

Figure 8 – The 3D Zcorp printer used for fabricating the parts

![Parts](image)

Figure 9 – Some pictures with the parts before making the hand assembly

7. Experimental Tests and Conclusions

Several tests have been made after finalizing the hand assembly. Some of typical prehension tasks are shown in the Figure 11:

![Hand assembly and actuation mechanism](image)

Figure 10 – The hand assembly and actuation mechanism
8. Conclusions:

The AH presented in this paper is the first one developed entirely at the Faculty of Mechanics, under the PhD programme called “Acknowledgements regarding the mechanical prehension systems”. For future research we will study the kinematics of the AH using the Simi Motion software for a typical prehension task and compare the results with those obtained for the human hand in the same situation. Although is a quite simple prehension device in terms of actuation system (using a single DC motor for all the three fingers), one can conclude that it is a promising start in the pursuit of constructing a dexterous hand similar to the human hand.

References: