I. INTRODUCTION

The design of upper limb prostheses must be done on realistic bases taking into account the present technologies and getting of the best efficiency in their use without ignoring the economical factors.

In authors’ opinion, the basic idea in the prosthetic field is that the quality must be measured not only through the technical performances of the prosthetic system but mainly through the performances the wearers get in the daily use of the system. Naturalness in operation beside cosmetics have to be the major factors in choosing of a certain type of prosthesis.

II. SPECIFIC ASPECTS ON UPPER LIMB PROSTHESSES DESIGN

The prehension mechanisms of upper limb prostheses have to emulate the functional and cosmetic characteristics of the human hand.

Finding of these studies has been that regarding the design of the fingers of prostheses which has not to be of anthropomorphic type as the human hand is [3].

Building of the fingers as a link chain, although useful in gripping of the objects of complex shapes, asks for sophisticated control systems which give the prosthesis a higher cost these resulting in the danger for the prosthesis of being rejected by the wearer because of the difficulties he encounters in using of it.

III. DESCRIPTION OF THE EXPERIMENTAL MODELS OF THE UPPER LIMB PROSTHESES

The four-bar mechanism is often used in the construction of prehension mechanisms, including those of prostheses, as it can be designed to reproduce a wide variety of kinematic conditions [12], [13], [14], [15].
In the prosthesis from fig. 2, a, b, c the fingers 1 and 7 are actuated by building them together with the four-bar mechanism ABCD.

The dimensions of the four-bar mechanism, for the initial adopted solution, in which the fingers move with same speed, are those in fig. 2c.

The dc motor 22, is of MT1P type (Electronica Industriala), 2W and 3200 rpm. It actuates the fingers through gears 24, 25, 30, 3, the planetary friction gear 4 and the worm gear 2 which prevent the hand to be opened accidentally.

The opening time is about 2 s and the objects to be manipulated with the prosthesis can be of up to 75 mm diameter.

The construction of this prosthesis is simple and as the motor 22 is placed in the palm, the prosthesis can be use for all levels of amputation including the long forearm amputations. The system 5 allows for passive supination. The control of prosthesis is of myoelectric, on-off type.

For the independent contour ABCDA, give a nonlinear system of 10 equations with unknown parameters BC, CD, AD, \( \Phi_i, \Phi_3, \Phi_2, i = 1, 5 \):

\[
\begin{align*}
DC \cdot \cos(\Phi_i + \Phi_3) + CB \cdot \cos(\Phi_3) &= X_A + BA \cdot \cos(\Phi_i + \Phi_3) \\
DC \cdot \sin(\Phi_i + \Phi_3) + CB \cdot \sin(\Phi_3) &= Y_A + BA \cdot \sin(\Phi_i + \Phi_3)
\end{align*}
\]

Solving of the above system of equations was done using a program named mecanism_proteza in which were used as initial conditions for BC, CD, AD, \( \Phi_i, \Phi_3 \), the already known dimensions of the mechanism (fig. 2c).

The final dimensions were obtained by multiplying the components of the vector \( X[i] \) with adopted valued for AB. The optimal solution for the mechanism was determined with an error \( \varepsilon = 0,000082 \), and was as follows:

\[
\begin{align*}
X[1] &= 2.2822812029E+00, \\
X[2] &= 4.6987603654E-01, \\
X[3] &= 2.7611665259E+00 \\
X[5] &= 1.8380572414E+00
\end{align*}
\]

IV. PROSTHESSES OPTIMISATION AND 3D MODELS

In order the prostheses emulate the kinematics of the human hand the first step was to do the synthesis of the four-bar mechanism [14],[15].

The prostheses having the rigid fingers shaped corresponding to the resting position of the hand was designed imposing five associated positions:

\( \Phi_i = \Phi_3(\Phi_3), i = 1, 5 \), the values for the angels, \( \Phi_3 \) (index) and \( \Phi_6 \) (thumb) being chosen from the graph from fig. 1 [1].

The equations projected on the coordinate system of the vectorial equation:

\[
DC + CB = DA + AB
\]
For AB = 15 mm it was got:

\[ BC = AB \cdot |X[1]| = 34.23 \text{ mm}; \quad CD = AB \cdot |X[2]| = 7.08 \text{ mm}; \]

\[ AD = AB \cdot |X[3]| = 14.14 \text{ mm}; \]

\[ \phi_1 = |X[4]| = -0.798 \text{ rad}; \quad \phi_2 = |X[5]| = 1.838 \text{ rad} \]

The designed mechanism analysed from kinematic point of view allow to obtain for the links CD (index) and AB (thumb) of different angels and speeds, the ratio OM31 = \(\omega_3/\omega_1\), having the values form the table 1.

### TABLE 1

<table>
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<th>( \omega_1 )</th>
<th>( \omega_3 )</th>
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<th>( \omega_4 )</th>
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<td>0.216</td>
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**V. CONCLUSIONS**

The 3D models of the two prostheses are presented in fig. 5 and 6. The program Solid Works used to build the models incorporates the module Cosmos Works with which can be done kinematic and dynamic studies very useful in the practice of mechanism design.

The theoretical results can be verified on the virtual models which validate the solutions and allows for optimisation of equipment, the overall cost of the final product being minimized because of the low conversion costs being implied.

### REFERENCES


