KINEMATICS DESIGN OF A MULTIFUNCTIONAL HAND PROSTHESIS

D. Razić

Introduction

The primary aim of the design of a hand prosthesis was to invent a mechanism that would approximate the movements of a natural hand and thus enable the hand prosthesis to produce sufficiently a great number of positions.

This aim has been realized by application of a particular appliance, the position integrator. In order to get the easiest and simplest hand construction for the bending of fingers, there have been used the non extendable steel ropes in an elastic coat (a spirally bent steel wire) conducted up to the position integrator.

By placing the integrator with the power block closer to the elbow a more favourable distribution of the total weight of the prosthesis can be obtained.

Basic kinematics principles of the prosthesis are simple and they are demonstrated in the enclosed pictures.

Kinematics Design for Fingers

Mechanism for the fingers is demonstrated in Figure 1. For a more detailed analysis and description of the mechanism, the fingers are denoted by the following letters,

P - thumb
K - fore-finger
S - middle finger
D - ring-finger
M - little finger

Likewise have been marked also the ropes, in which tension produces bending of any particular finger. The manner of finger bending is dependent on the place of jointing the rope which has been pulled tight and on the relation between the forestress and stiffness of the springs in all the knuckles. Springs in the finger knuckles serve for adjustment, i.e. for returning the hand from the various positions to its basic position (the fingers strenghtened and put together with each other, the thumb moved aside, as in Figure 1a.

The mechanism and manner in dragging through of the ropes at the fore-finger, middle finger, ring finger and little finger are

similar, except at the fore-finger there is also an additional rope "K_2" (Fig. 1b). Ropes "K_0", "S_0", "D_0" and "M_0" regulate the angles of bending in the first two of the knuckles, whereas the tightening of the ropes "K_1", "S_1", "D_1" and "M_1" may produce and lead to the various bendings of the fingers, viz.:

- bending in the first two of the knuckles,
- bending in the third knuckle,
- bending in all three knuckles.

Such flexibility enables the selfadjustment of finger bending with the form of the object in hand.

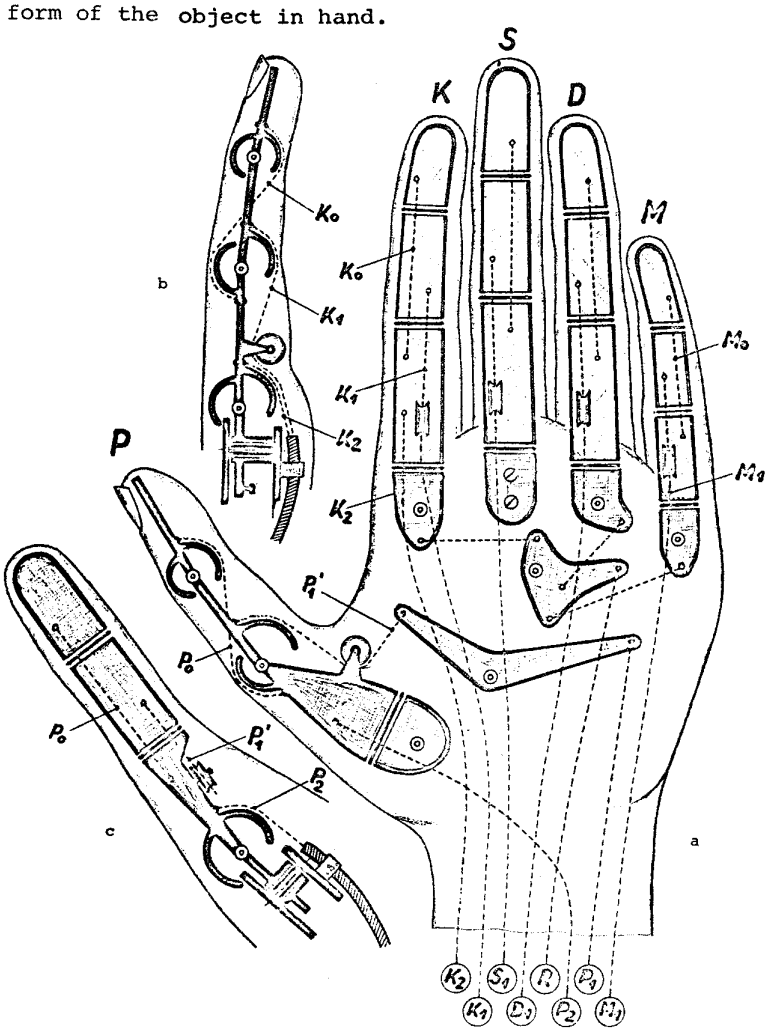


Fig. 1.

If the hand is empty, the course of finger bendings will depend only on the forestress and stiffness of springs in finger knuckles. Beside the bendings, it is also possible to widen the fingers, singly or all of them together, the middle finger being fixed in relation to the palm. This has been made possible by a particular construction of the last knuckle of the fingers. The widening of fingers is achieved by a three-pronged lever, or by pulling tight the rope "R" (Fig. 1a).

Kinematics Design for Thumb

The mechanism of the thumb is shown in Figure 1a and 1c. There exists a complete analogy with the mechanism of the other fingers. The bending axes in the second and third knuckle are mutually turned around for a definite angle (about 75°), while the last knuckle is in form of a joint fixed between the plates of the palm.

In the basic position of the hand, the thumb is streched out and in a fallen position. By pulling tight the rope "P_2", the thumb is raised to a determined limit (bending in the third knuckle). If, thereafter, by the rope "P_1" through the doublepronged lever the tightening is made, the rope "P_1" will produce the bending of the thumb in the first two knuckles and rotation in the last knuckle. By pulling tight the rope "P_1" without preliminary raising of the thumb, bending in the first two and in the last knuckle of the thumb will occur.

Palm Construction

The palm is made of two parallel plates between which there are in form of joints the last knuckles of fingers fixed together, and also fixed the lever for widening of fingers and lever for tightening of the thumb. The plates are in the corresponding spots perforated to provide access for the power ropes and for their adequate conduct to the position integrator. Thus, it simultaneously diminishes the weight without any signaficant weakening of the solidity of the plates.

Kinematics Design for Wrist

The design for wrist is shown in Figure 3. The parts of the wrist are:

(1) palm construction,
(2) joining plate,
(3) distance lever,

(4) top of forearm.

The listed elements make the kinematics polygon which sufficiently exact produces bendings that approximate the motion of the natural wrist of the hand.

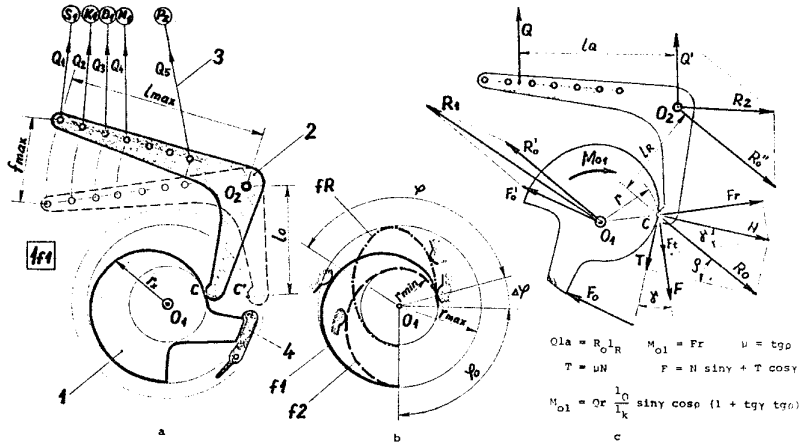


Fig. 2.

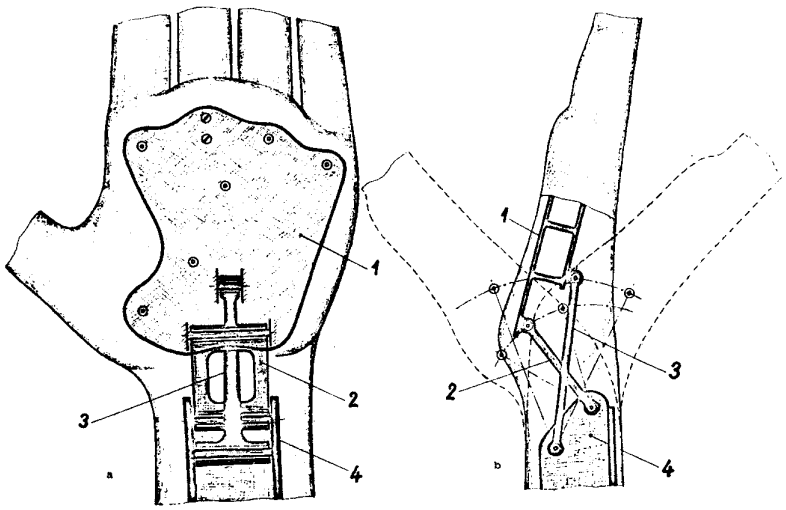


Fig. 3.

Position Integrator

The position integrator is a complex combination of more elements which all together enable the hand prosthesis to be transferred into the various positions. The position integrator consists of:

- Loose endings of the power ropes which are worked out in the form of chains and in the scheme of the integrator (Fig. 4a) they are represented by the small circles with the corresponding marks of the ropes.
- Roller mechanisms, i.e. six levers placed in parallel (pos. 2 in Fig. 2a) and roller plates (pos. 1). Each lever is in contact with the corresponding plate (roller plate), the working surface of which may be varied. The roller mechanism are represented in the scheme of the position integrator (Fig. 4a) as squares with corresponding marks. The index in the marks describe the form of working surface of the proper roller plate, the variants of them being shown in Figure 2b. Thus, at the same time, there has been defined the timetable of raising of the singular levers at the simultaneous rotation of more roller plates.
- Elements for integration of elementary hand positions. These elements connect the loose endings of ropes and the levers of the roller mechanisms, and in the scheme of the integrator (Fig. 4a) they are represented by straight lines which link the circles and the squares. They may be a bit thinner steel ropes and are used for integration of the precise positions, or elastically extendable elements and are used for integration of gripping movements where the best possible adjustment of the fingers to the form of objects on the hand is required. At the same time, the elements for integration ensure that the power ropes are not overloaded and in their construction they are simple and may easily be replaced. The place of joining of the elements on the lever of the roller mechanism (pos. 3 Fig. 2a), i.e. the length of arm "l_Q" depends on the necessary extension of the determined rope. The same regulation may be made also by the length of the elements for integration, or by preliminary surplus of the length. All such combinations together give broad possibilities for integration of various positions and of their nuances.

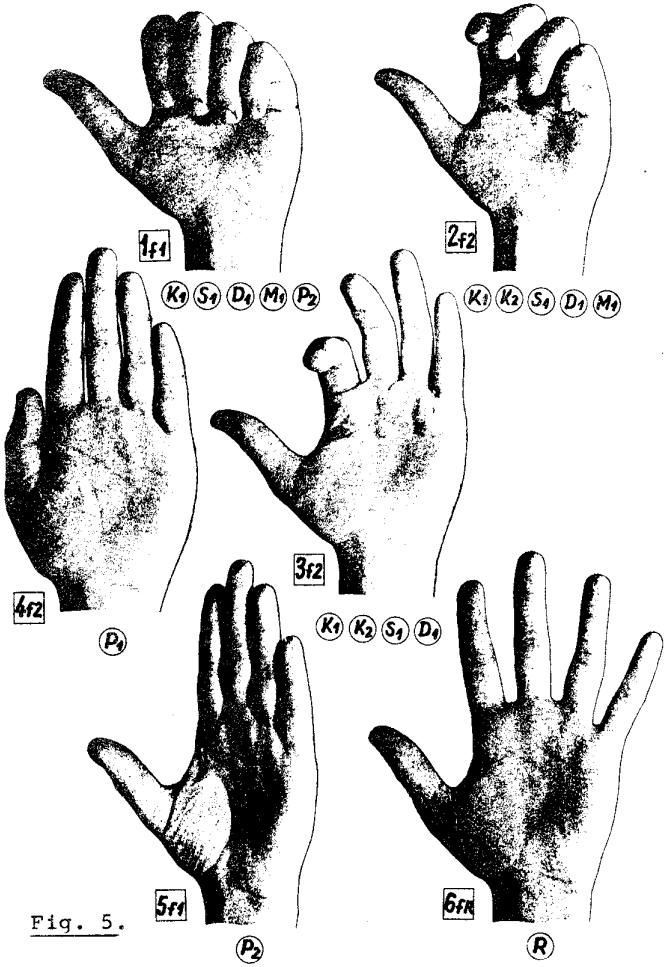
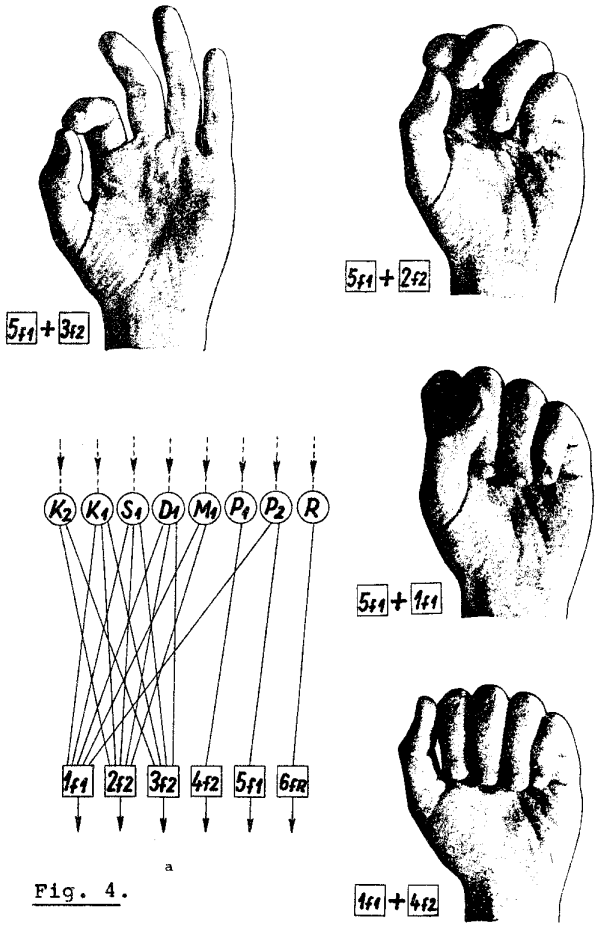

1f1
2f2
K1 S1 D1 M1 P2
K1 K2 S1 D1 M1
4f2
3f2
P1
K1 K2 S1 D1
5f1
6fR
P2
R

Fig. 5.


5f1 + 3f2
5f1 + 2f2
K2 K1 S1 D1 M1 P1 P2 R
1f1 2f2 3f2 4f2 5f1 6fR
5f1 + 1f1
1f1 + 4f2

a

Fig. 4.

Elementary and Combined Positions

By pulling tight each lever of the roller mechanism singulary, the hand goes into the corresponding elementary position. In Figure 3, there are shown some elementary positions of the hand. By simultaneously putting into activity more roller mechanisms, the combined positions take place, e.g. as in Figure 4. In such case, the timetable of the elementary positions is defined exactly in the complexity of the combined position giving the possibility of a regular and easy manipulation of the prosthesis.

The transfer from some position into any other position must be carried out at first by returning into the basic position of the hand and then into such other position. Activation of the roller mechanism, or of the roller plates, is performed by use of the special hooks (pos. 4 in Figure 2a) on the common power platform. The joining of singular hooks and of their combinations is made by **electromagnets**, automatically, after reception of the corresponding signals.