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DEVELOPMENT OF DELTA-TYPE PARALLEL ROBOT USING PNEUMATIC ARTIFICIAL MUSCLES IN APPLICATION FOR REHABILITATION

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Abstract: . *This article presents a construction prototype of delta 3-DOF parallel robot. The device is used to rehabilitate people with upper limb dysfunction. The combination of pneumatic muscles and electric drive were used to move this device. Base on conducted research we determined workspace of the drives and its shape. The article contains description of prepared application and applied procedures.*

Keywords: parallel robot, 3-DOF, workspace

1. Introduction

Recently there has been a significant increase in construction of parallel robots. Manipulators and parallel robots are more widely applied in medicine. Robots with closed kinematic chain are characterized by large rigidity, better positioning repeatability and manipulation precision. They have better capacity, acceleration and effector velocity. Due to their fast response and movement precision, parallel robots are mainly applied in pick-and-place applications. Delta is a parallel robot with three degrees of freedom that belong to a group of manipulators with a special articulated construction of a moveable platform. It is comprised of three identical kinematic chains, three drives symmetrically arranged on the drives' basis (of rotary movement) in relation to the vertical axis of robot base system and a symmetrical moveable articulated platform.

Robots are increasingly being used in medicine to assist surgeons during surgery (Zidek and Maxim, 2011). Similarly, robotic rehabilitation applications are used. Currently, there is a great need for using of such devices in people rehabilitation with limb dysfunctions.

For this purpose, a delta robot was designed, which in its kinematic chain has artificial pneumatic muscles (Takosoglu, 2016). The device will help to support movement and strengthen the muscle strength of patients during rehabilitation exercises.

It will also facilitate the movement of patients with neurogenic dysfunction of the upper limb movement organ. Dysfunction may affect patients with nervous system paralysis and patients with neurological and orthopedic injuries. The use of artificial pneumatic muscles that mimic the work of human muscles will allow for smooth movements and protect against excessive loading. The device uses a teaching/repeating control method to manually move work platform based on known movement patterns used in people physiotherapy with neurogenic motion dysfunction.

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2. Movement patterns

In order to determine shape of workspace and range of effector movements, typical movement patterns were recorded (Fig. 1). The tests were performed in a rehabilitation medical center. Obtained trajectories allowed to conduct simulation tests of joints work ranges included in the mechanisms of active and passive arms of the device. Lengths of construction elements were determined, including the shape of the arms or the size of the work platform. Determination of movement patterns took place during the exercise done by a professional physiotherapist. The scene was prepared with a vernier scale in the form of a black and white chessboard with well-known dimensions. It allowed to determine motion trajectory of the recorded sequences. During implementation of the task, a number of analyzes were carried out, mainly static and dynamic tests of the main drives of the device, including artificial pneumatic muscles (Pietrala, 2017).

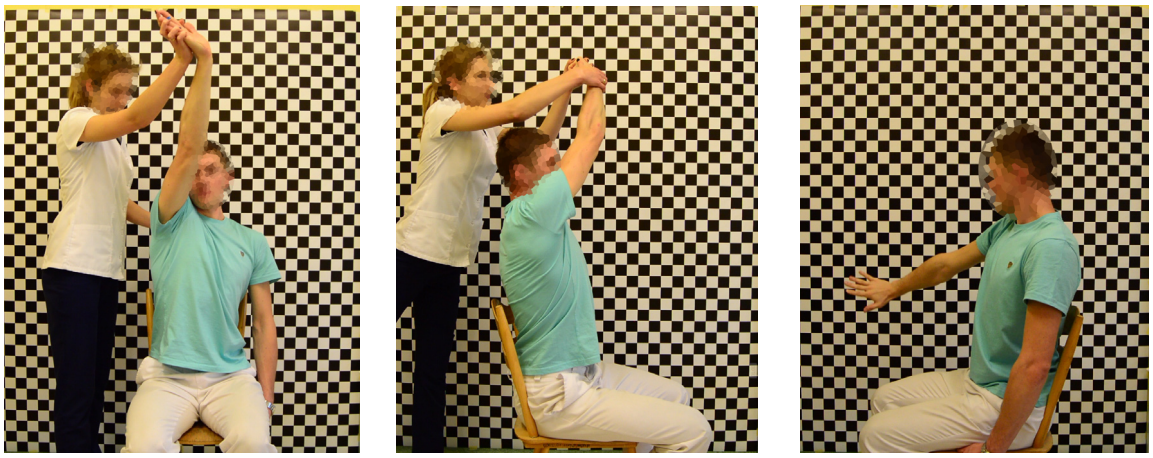

Fig. 1. Sample photos of experimental tests perform to determine movement patterns

3. Solid model of delta 3-DoF manipulator

The manipulator was designed based on the construction of parallel robots of three degrees of freedom. Its solid model, which was made in 3D CAD program, is presented in Fig. 2. The robot consists of fixed basis, moveable articulated platform and three identical kinematic chains connecting them.

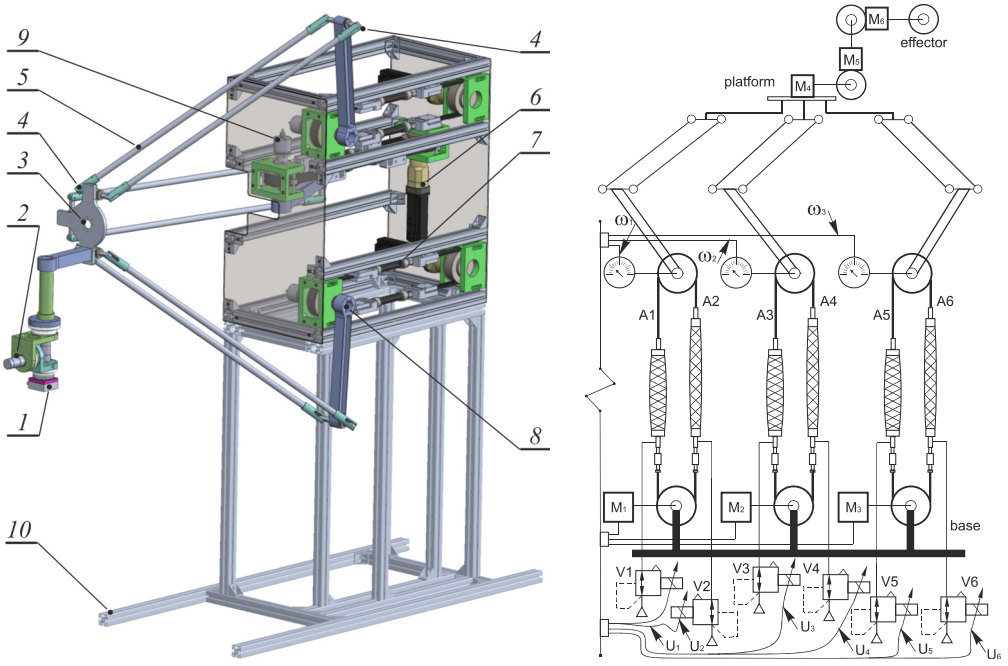

Fig. 2. Solid model of delta 3-DoF parallel manipulator, 1 ï effector, 2 ï electric drive platform (DC servo motor), 3 ï operating platform, 4 ï joint, 5 ï passive arms, 6 ï ï drive (AC servo motor), 7 ï pneumatic muscle, 8 ï active arm, 9 ï encoder (sensor of angular position), 10 ï base.

The robot is symmetrical in relation to the basis center. Its mechanisms are arranged on the basis on a plan of triangle. Each kinematic chain consists of active and passive drive elements. A drive arm (active) is an aluminum profile, which is mounted to the shift on one side, and its second end is pinned to passive elements of the shaft with the use of spacer elements. The shaft is mounted in the rotating joint of one degree of freedom that connects the active arm with the robot basis. Rotation axis of the shaft is connected with the sensor of angular position of the robot arm. To process the movement of the drive arm to the moveable operating platform, two aluminum pipes ended with spherical joints were applied.

Drive of the robot working platform consists of three pairs of muscle drives and three servo motors. This configuration helps to set proper position of the robot in its workspace. On the triangle working platform there are additionally mounted three drives connected in series. They are responsible for determining the orientation.

4. Workspace of delta 3-DoF manipulator

Manipulator operating space is a set of points in space to which its end might be led. Both size and shape of the operating space depend on the type of the robot mechanical construction, geometric dimensions and the range of movement of particular manipulator elements.

For the designed *delta* 3-DOF manipulator, the operating space was determined with the use of space discretization method for a set of points. Therefore, a net of equidistant (in every axis) points in the form of a cube with the following dimensions $x \in \langle -600, 600 \rangle$ mm , $y \in \langle -600, 600 \rangle$ mm , $z \in \langle -500, 1400 \rangle$ mm was generated. Subsequently, a set of points was chosen for which it was possible to solve the problem of inverse kinematics (under the condition that the articulated variables of all active manipulator arms fulfil the following condition $q_i \in \langle -35°, 35° \rangle$). The operating space was determined for a rotary angle of the articulated moveable platform $\theta = 0°$. Its overview is presented in Fig 3.

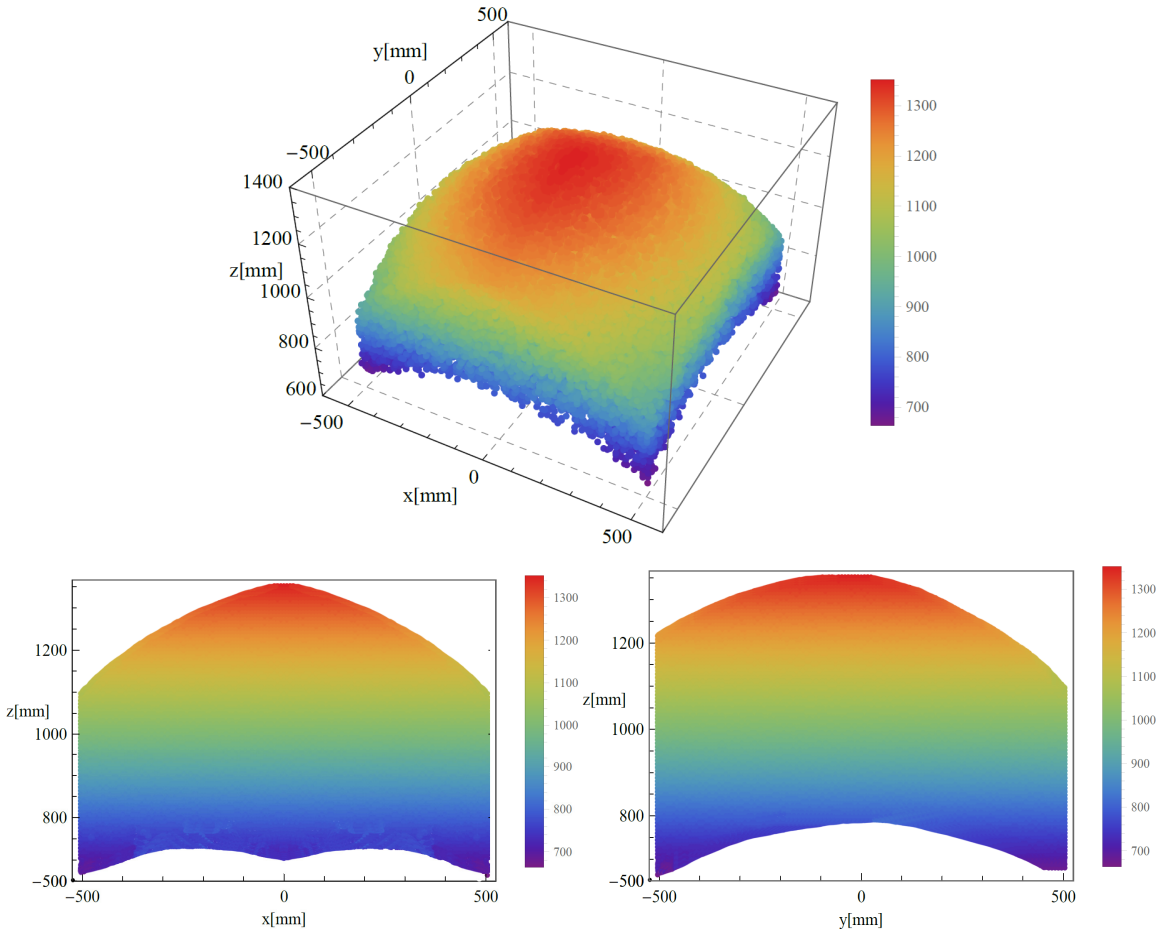

Fig. 3. Manipulator operating space: a) general overview, b) view in xy plane, c) view in zy plane.

5. Conclusion and future work

This article describes a new type delta parallel manipulator. Currently, there is a very large need for rehabilitation equipment. Every year in the world, thousands of people are injured, and they require long-term rehabilitation. Presented device allows the physiotherapist (doctor) to move patient's hand on the teach correct trajectory and then the device can replay this path. In this process robot controls position and movement strength. The characteristic of the 3-DoF delta manipulator, including the size of the workspace and working ranges, are highly reliant on the parameters of the kinematic structure. The lengths of the arms and axis ranges achievable by the spherical joints have the most impact on the shape of the workspace.

Therefore, the possibility of physiotherapists support in the rehabilitation of people with disabilities may in the future become a standard medical procedure.

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