SUMMARY

SUMMARY OF THE DOCTORTAL THESIS

"Modular control system for a musculoskeletal rehabilitation robot with force feedback"

Limb rehabilitation to restore lost function is a long-term process. In this process, the physiotherapist manually moves the rehabilitated limb of the patient during exercises that usually last for months and require a lot of physical effort. To reduce the fatigue of the physiotherapist and, at the same time, ensure greater repeatability of the applied therapeutic exercises, various types of mechanical and mechatronic devices began to be introduced, which currently, in their most advanced form, have taken the form of rehabilitation robots.

The subject of this study was the design and validation of a control system for a rehabilitation robot with multiple degrees of freedom, in which force feedback was used to control the robot. Taking up such a research topic resulted from the work carried out at the Institute of Medical Technology and Equipment ITAM in the area of rehabilitation robot design and implementation. The result of the research and design work carried out at ITAM in 2007÷2009 was the prototype of the ARM-100 rehabilitation robot. This robot, in the form of an exoskeleton, enabled the performance of multi-planar therapeutic movements.

On the basis of a wide range of testing and validation studies of the ARM-100 rehabilitation robot prototype, directions for further development of the developed solution were identified. One of the most important conclusions was the need to develop a new control system, which, based on the data from the measurement sensors, would be able to determine the intention of movement in the joints, and the robot's drive components would support this movement. In 2017, work began at ITAM to develop a further improved version of the ARM-200 upper limb rehabilitation robot, and the execution of this implementation PhD was closely linked to this work, primarily in the development of the control system. In the course of the design work related to the development of the new version of the robot, functional and normative requirements were identified, which formed the basis for the formulation of the aim of

the thesis, which was directed towards the development and validation of a control system for a rehabilitation robot designed for upper limb therapy using force coupling to realise the robot's movements. The scope of the research work carried out in the dissertation was refined by the adopted research theses as follows:

1 The data from the force measurement sensors placed at the individual nodes of the rehabilitation robot can be used to automatically detect movement intentions in the patient's upper limb joints and to control the robot's movement trajectory.

2. The introduction in the robot's movement control algorithm of the minimum force required to activate the actuators (so-called insensitivity thresholds) will contribute to increasing patient safety by eliminating unwanted robot movements.

3. The use of a control application operating in a non-real-time system to control the operation of the rehabilitation robot will not adversely affect the operation of the robot control system.

The final result of the completed design and implementation work was the development of a control system for a rehabilitation robot for upper limb therapy. An important element of this control system was the development of control algorithms to enable automatic detection of joint movement intentions and to support this movement. The designed and manufactured prototype of the rehabilitation robot was used in research work, the main aim of which was to validate the developed control system.

The results obtained from the validation tests of the control system components of the upper limb rehabilitation robot confirmed the correctness of their operation and the fulfilment of the functional and normative requirements of the designed and manufactured rehabilitation robot prototype. The theses of the study were also confirmed on the basis of the conducted experimental tests.