Gait can be defined as rhythmical loss and restoration of a balance in alternately changing phases of support and move. Keeping a balance during locomotion is obtained by numerous factors including proper balancing the body, reducing or increasing the length of the steps and their frequency, monitoring the constant or changing reference points as well as precise activation of particular muscles and groups of muscles. The natural human gait requires constant control and correction of its parameters. In healthy person this process is conducted automatically thanks to, among others, signals sent to the brain by the labyrinth and receptors located within the skin. In people with the locomor system dysfunction the process of automatic retrieval of the balance is often disrupted what makes movement harder or even impossible to perform. In these cases it is necessary to apply external assistance systems. Depending on the type and the extent of the disability various systems are used including parapodia, static or dynamic standing frames and lately orthoses in a form of exoskeletons of lower limbs. The first device of the latter type of the assistance systems equipped with own drive system was the exoskeleton named Hardiman (Fig.1) which was made in 1965 by General Electronics for the US army. The exoskeleton was of large dimensions and did not allow for wide freedom of motion. In addition, the lack of the stability and problems with the power supply lead to the shutdown of the project which remained a milestone in the development of technology giving an inspiration to further constructors of the exoskeletons.

Fig. 1. Hardiman exoskeleton

Although the exoskeletons produced nowadays are far more advanced in technology than their first prototypes and, in some of the cases, are the constructions which are mature in terms of their functionality, still a lot of problems important from the point of view of the comfort of use, universality, modularity and possibilities of an adaptation to the needs of the user has to be solved. Hence, further research on improving these devices and better understanding of anatomy and physiology of the human locomotor system itself (as an object assisted by an exoskeleton) seems natural and desired.

The proposed study aims at creating a set of guidelines regarding the construction of a functional exoskeleton devoted to the rehabilitation of the people with lower limbs impairment. Its integral part is the development of a prototype of the exoskeleton based on preceding theoretical analyses to confirm formulated assumptions and define the critical components of the construction requiring special attention and care in both design and creation processes. Additional advantage of a physical implementation of the exoskeleton design will be the possibility of conducting with its use the examinations of kinematic and dynamic parameters of gait as well as investigating construction solutions of the exoskeleton itself. The aforementioned will let to acquire the information enabling the optimization of further versions of the device regarding mechanical construction, drive system and control.

The motivations to undertake the research within the study being presented are the utilitarian nature of the problem resulting from the real medical and social needs and, on the other hand, the experience of the project executive team members regarding the field of the study. Some of the tasks provided for in the study have been already initialized and their first results indicate the correct direction of the research and are promising in terms of the final result. The aforementioned refers in particular to the modeling of muscles, detection of their activation in motion, new solutions regarding the development and design of the screw-hydraulic actuators, what is closely connected to the topic of the drive of an exoskeleton, the analysis of the knee joint kinematics, locomotive stability of a human as well as related algorithms and software to identify the images in motion.

The study will be implemented in two stages. The first stage will include the preparation of the theoretical background for the design of an exoskeleton. Within this part of the study it is planned to, among others, conduct detailed analysis, both kinematic and dynamic, of lower limbs during gait; to develop new and optimization of existing mathematical models of muscles and methods of their parameters identification; to analyze the effectiveness of various methods of identifying the activity of lower limb muscle groups in particular gait phases; to develop possibly exact mechanisms to simulate kinematics of the hip, knee and ankle joints; to develop a concept of an exoskeleton control as well as to estimate the ultimate and fatigue strengths of the exoskeleton by means of numerical studies with the use of the FEM (Finite Elements Method).

The second, experimental part of the study will be devoted to the physical implementation of a prototype of an exoskeleton based on the results of the theoretical investigations and conducting a series of analyses and measurements verifying the most important kinematic and dynamic parameters of the exoskeleton itself as well as of the human-exoskeleton system. Gathering the information regarding the interaction of an exoskeleton with corresponding biological model and their kinematic biocompatibility will be particularly important. This aspect has an essential impact on the user comfort and decides on the practical usability of the device. It is planned to, among others, experimentally validate the mathematical models of muscles; test the physical model of an exoskeleton in the condition of normal gait; analyze the motor stability of the human-exoskeleton system; check the compatibility of the theoretical trajectories and ranges of motion of particular exoskeleton elements with their real equivalents being the results of the experiments.

The study will be followed by the set of conclusions and recommendations regarding the construction of a lower limb exoskeleton that will be developed on the basis of theoretical analysis and experimental studies with the use of the created prototype of the device.

The first global experiences connected to the use of exoskeletons in the rehabilitation of the human locomotor system provide the background to the conclusion that exoskeletons can be one of the most important and most effective tools in the process of restoring (or at least improving) the locomotion in the people with different types of dysfunctions of the lower limb. The authors of the study expect that the results of their research will actually lead to the initiation of the production of such devices in a mass scale with simultaneous keeping of relatively low production costs. The factors that will be decisive are the affordable price, the quality of the construction and the comfort of use. The subordination of the research tasks to the aforementioned purposes should not limit the universality of the achieved results, but strengthen their utilitarian nature.

The results of the research should lead to the reduction of the exoskeletons production costs and simultaneously make their adjustment to the personal needs of the user resulting from their physical structure and the type of the dysfunction easier. Although the study is focused mainly on the applications in the rehabilitation, the experience gained during implementation of the study can be used also for other purposes, i.e. for the construction of specialized two-legged robots or exoskeletons for military and industrial purpose.