NEW MODEL OF AUTONOMOUS "ACTIVE SUIT" FOR DISTROPHIC PATIENTS

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A b s t r a c t

In the paper the new model of the "Active suit" - type of active orthosis for supplementing walking power to distrophic patients is described. Main problem of autonomous power supply has been solved by mounting a battery of Ni-Cd accumulators on the back of the orthosis main corselet. The autonomy is about 1 hour walking time upon predominantly level surface. The control system, containing an INTEL 8085 - based microcomputer, output servoamplifiers and all controls (switches, selectors, buttons and LED indicator) are mounted in a flat light metal box, situated on the front (chest) side of the main corselet of the orthosis. Main new types of control are: variators of gait speed and step size, gait type selector (upon level ground, up- stairs and downstairs), together with a turning control to facilitate changing of direction during walking. First series of trials with this new type of active orthosis showed satisfactory results. Further development and improvement, concerning primarily weight reduction and implementation of new programmes into the control system are planned.

Introduction

Biped walking machines in the form known as "Active exoskeletons” have been developed, assigned and built several years ago by the Robotics Department of the Mihailo Pupin Institute, Beograd, Yugoslavia (1, 2, 3). By using the contemporarily available materials, components and technologies, the exoskeletons proved to be slightly “ahead of their time”, because they stayed still too heavy, complex and expensive for some broader application. In some times to come fairly soon, it is hoped, that the availability of lighter, stronger and cheaper materials and components will enable the realization of applicable active exoskeletons. Some positive experience with foreign-designed active exoskeletons, based on our ideas and basic solutions (4, 5), keeps us convicted, that exoskeletons will return as the only feasible means of rehabilitating handicapped persons without any motoric activity of their own legs, i.e. paraplegics and similar patients.

In the meantime, a specific type of active orthosis has been under development from 1975. in the Mihailo Pupin Institute under the name "Active suit". The current progress in that project has been regularly reported (1, 3, 6). It is necessary

to summarize in short the principal advantages of this design

over the "Active Exosceletons":

- modular design, enabling realization of active orthoses with the needed number of active joints, from one to six,

- considerably lighter construction and easier "taking on", "carrying" and "taking off",

- sensibly lower price, due to the unification and standardization of the suit modular components, which can be produced in a few standard sizes only.

The disadvantage of the "Active suit" lies in the needs, that the patient possesses the stability functions and, at least rudimentary muscular power for stability purposes. Thus the type of patients for 'rehabilitations is the rather numerous group, under the general name "distrophical", with progressive neuromuscular diseases of variable etymology.

New Model of the "Active suit"

There exists considerable difference of the new model of the "Active suit" in its favour, as compared with the preceding model, illustrated in Fig.1 and 2 (7).

Fig.1 Preceding model of the "Active suit"

Fig.2 Trials with the "Active suit" from Fig.1

Fig.3 New model of "Active suit"- sideview

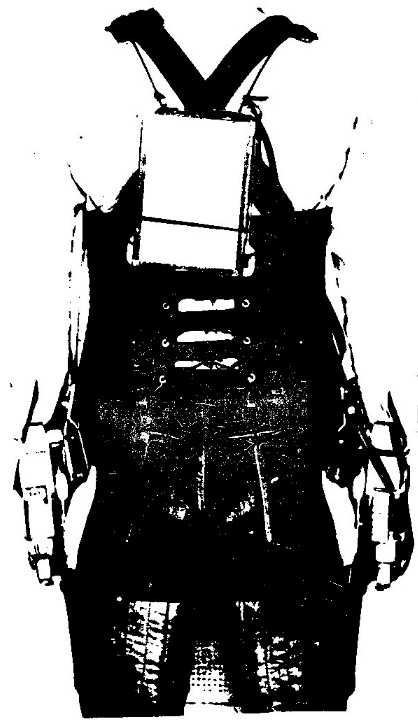


Fig.4 New model of "Active suit" - backview

In Figs.3 and 4 is presented the new model of the "Active suit" developed in the course of 1980/81. It is based on the slightly modified basic structure of strong textiles with metal and plastic inserts for reinforcement which are introduced in corresponding "pockets", sewn into the basic structure,(Fig.5). On the chest can be seen the control system box, which contains the microcomputer and servoamplifiers (Fig.3), and on the back (Fig.4) can be seen the battery pack, containing the Ni-Cd accumulators, fuses and harness. This will be described in detail later.

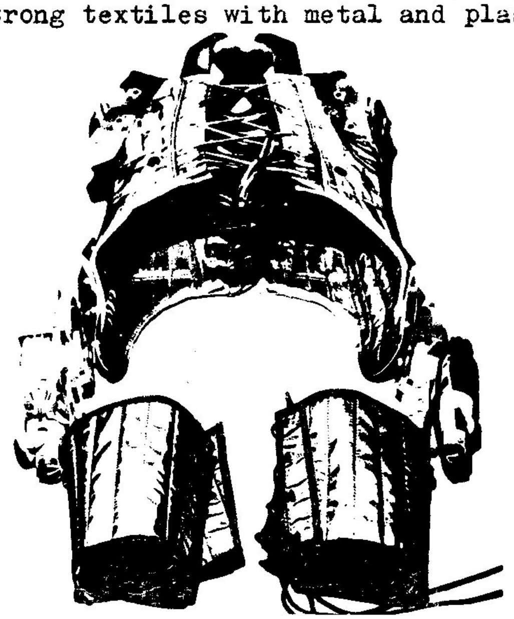


Fig.5 (right) Basic structure of the "Active suit".

The standard hip - knee joint actuator is shown in Fig.6. It should be reminded, that it has been designed around two miniature industrial D.C. permanent-magnet servomotors, having short-term output of 50 Watts each, which are coupled via precision bevel gearing and mechanical reducer of ratio 1 : 100 to the artificial joint shaft. One motor is equiped with a miniature tachogenerator, which yileds the very useful possibility of velocity feedback. The unit weighs 1,6 kilograms only and is to our knowledge the lightest bio-robotic actuator for its weight and output. In the trials up to now it showed high reliability and sufficient power output, for instance, for level walk of a certain distrophic patient, one motor could be removed from each actuator. Improvement can be done in sound-proofing the gearing and further (but very slight) weight reduction.

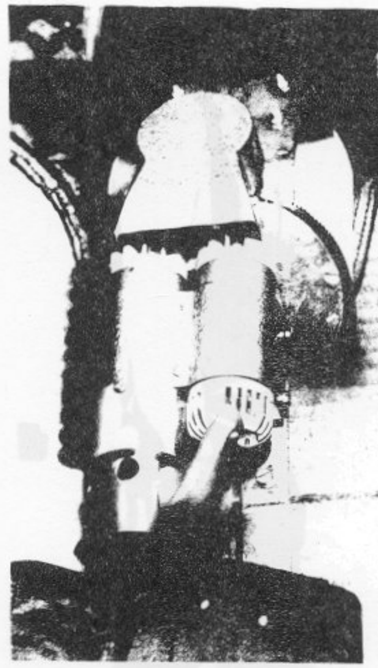


Fig.6 Actuator of the "Active suit" joints

The battery pack is presented in Fig.7, closed in the upper, and opened in the lower illustration. The box itself was manufactured from thin metal sheet, and contains 24 Ni-Cd accumulators of 1,8 Ah capacity of the fast charge - discharge type. The cover is held in place by four screws. Weight of the whole battery pack is slightly under 2 kilograms. The inside of the box is covered by felt.

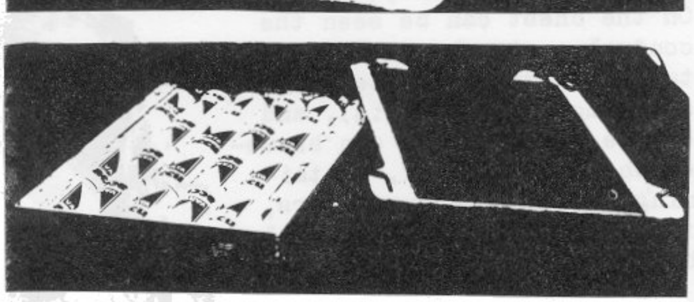


Fig.7 Battery pack of the "Active suit"; above - closed, below - opened

Control System of "Active Suit"

The control system will be described under separate heading, because it represents a complete novelty as compared with the old solution (7). Together with the previously described battery pack, it represents the basic means for complete autonomy during the gait and use. A fast electronically controlled charger, not to be presented here being a standard unit, completes

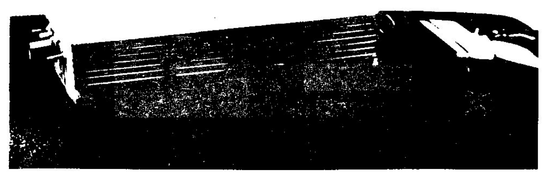
the whole "Active suit" system.

Mechanically, the control system, shown also in Fig-3, is

in the form of a flat box, made from thin metal sheet, Fig.8, above. The output powerful transistors can be seen under the Protective plastic grid. On the right side can be distinguished the flat multi-pole connector to the battery pack and actuators. The controls, situated on the top side of the control box when in use, are on the left side of the lying system in Fig.8. They will be described in detail in the text to follow.

in Fig.8 below, the opened servoeye.te5 box is shown. Clearly can be distinguished the printed circuit board of the microcomputer and memories at left and the beard of the servo-systems at right side of the photo. The mating connector of the above-described part at the end of the connecting cables can also be seen. The female connector of the boards are swivel-mounted, so they can be turned for a certain angle to enable pushing in and pulling out the

control system box weighs approx. 1 kilogram.



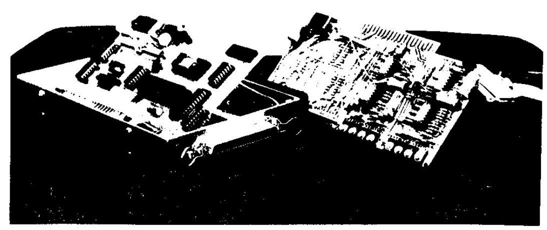
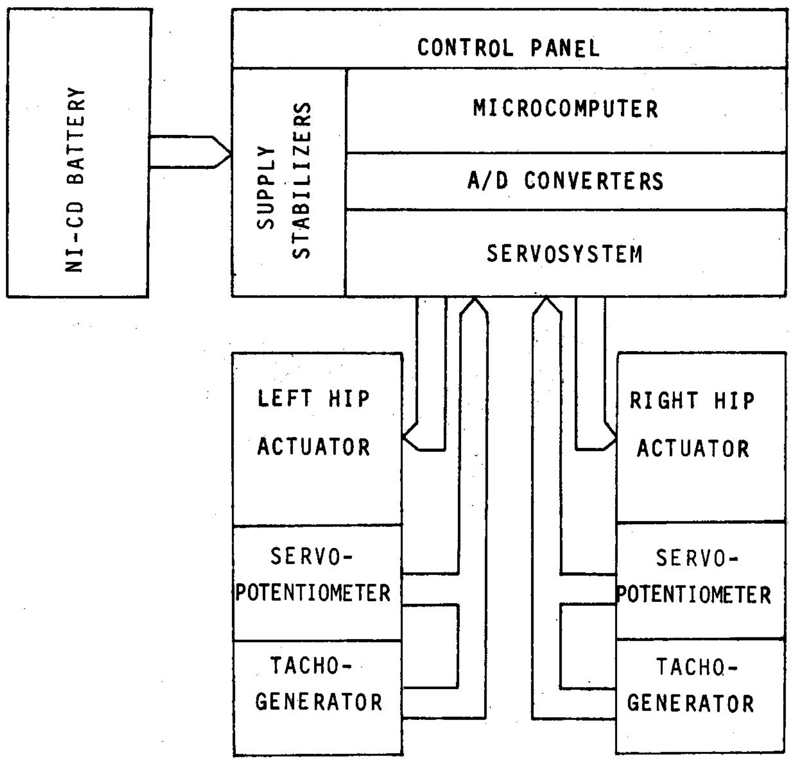


Fig.8 Control system box, above - closed, below - opened.

On the microcomputer and memory board there are still unoccupied sockets for more memory chips, so that beside the existing three gait types, other locomotor acts can be added.

Block-scheme of the control system is given in Fig.9 , enclosing three interconnected entities, indispensable for normal operation of the whole system.

The Ni-Cd battery enables electrical supply of the actuators and electronic part of the control system, independently from the electrical mains. The D.C. servomotors with mechanical reducers, connected by means of the body and leg semi-soft corselets to the patient's body, ensure direct help to the handicapped during gait by supplementing the needed power for the selected gait type.



The control system itself consists of a microcomputer, based on the INTEL 8085 microprocessor, the programmes, ensuring the necessary spatial and time functions of the gait parameters, the control panel and the analog servosystem with position and velocity feedback.

The autonomy of the whole artificial locomotion system is primarily expressed in the energetic independence from the mains supply. Application of the Ni-Cd batteries as movable supply.

is at the contemporary technological development level the optimal solution, keeping in mind the deciding parameters, the specific volume and energetical density, price, mechanical and electrical reliability, insensitivity to deep discharge, durability and simplicity of use. The voltage of the battery was dictated by the motor tensions, and the capacity was chosen as a compromise between two opposite tendencies: augmentation of the working time autonomy and reduction of the whole system weight, in which the battery pack participates with approx. 30 %, having in mind a patient of medium weight.

The patient controls the work of the system by means of a control panel, situated at the top side of the control system box. On one side, the task was to offer the patient maximum influence on the control system behavior, but on the other side, due to the needs to minimize the dimensions and weight and ensure simplicity of use, the control panel had to be the smallest and simplest possible. The adopted solution, presented in Fig.10, disposes of the following controls and indicators:

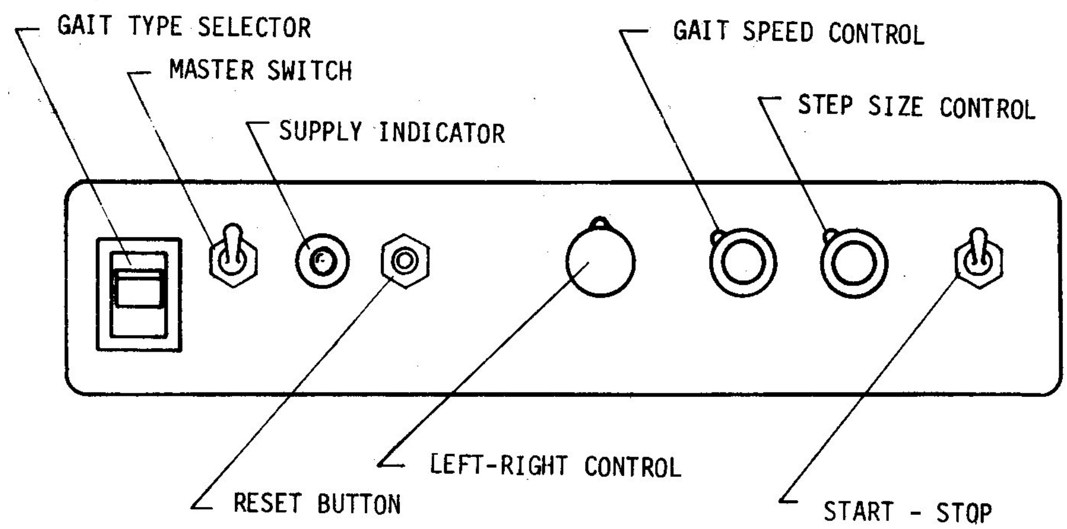


Fig.10 Control panel of "Active suit" (Scale 1 : 1)

1. Gait type selector (upon level ground, upstairs, downstairs) 2. Master switch - for switching the supply of system on - off 3. Supply indicator - LED, showing the battery pack charge

4. Reset button - for resetting the microcomputer

5. Left - right control - for aiding turning during gait

6. Gait speed control   for controlling gait frequency

7. Step size control   for controlling the step size (stride)

8. Start - stop switch - for staring and stipping gait.

Great care has been dedicated to the protection against incorrect and careless operation, which could lead to patient injury or damage of the control system. Start of the gait is by the left leg always, so that the patient can learn this easily. Stopping can be ordered in any moment and situation, but it will always end by finishing a half-period of the started step by enclosing the moving leg to standstill. By operating the master switch, the system will not move, but only after activating the start-stop control, under the condition, that all selectors have been previously set neutrally.

Using the potentiometers is for two basic applications: adjusting the system operation to the concrete patient and changing the dynamics and direction of gait; yet the end positions have been selected in such manner, that by incorrect operation the patient cannot impair his security.

The Supply indicator of the battery charge state has an orientary function only, because even in the case of deep discharge uncontrolled behaviour of the electronic system cannot occur, before all because of the fact, that its threshold of correct operation lies below 2/3 of the nominal battery voltage, in which the batteries cannot move even the unloaded actuators. Since the control system and actuators use the same supply source, and the actuator motors are alimented due to smaller heat dissipation on the transistors, in pulse form, the current and voltage shocks are fairly strong, so much attention has been dedicated to voltage stabilization of the control system itself.

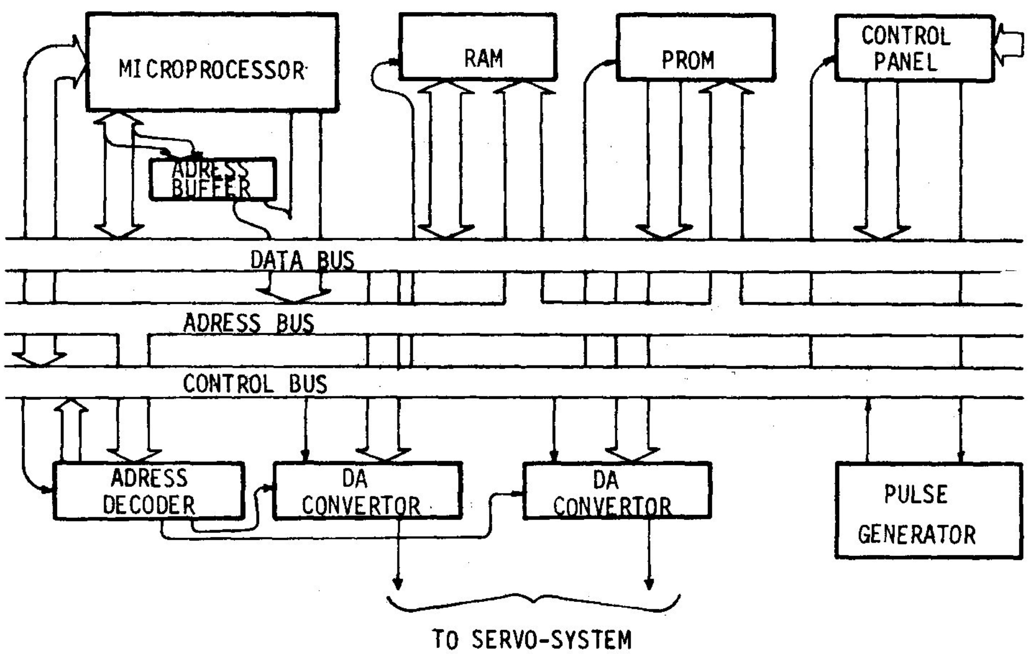


Fig.11 Block-scheme of control system microcomputer

The block-scheme of the control system microcomputer is given in Fig. 11. The micro-computer has been formed around the INTEL 8085 microprocessor. Fixed (EPROM) memory is used for storing the programme and the tables of the nominal trajectories of leg angles for the individual gait types, while the temporary (RAM) memory is used for storing the live registers and the inter- mediate values during computation. The nominal trajectories are prescribed to the servo system by means of 8 - bit D/A converters. Tables with the values of the individual programme points contain 40 point each per a half-period of each stationary regime and 15 points each of each transient regime. Software of the control system enables a quasi-linear approximation of the nominal trajectories on the segments between the points from tables. Apart that, the micro-computer ensures protection against improper operation and handling, choice of the working regime and automatic transfer from the transient into stationary regimes and vice versa.

The servo system of the autonomous artificial locomotion system contains identical independent servo system for each joint. Each servo system receives the command signal from its D/A converter and works as a positional servo, but uses the velocity feedback via the tacho-generator for sake of the realization of better dynamical characteristics.

Conclusion

After a series of very satisfactory experimental trials with the chosen distrophic patient, including verification of

the new gait types over programmed obstacles (upstairs, down- stairs), the contemporary new model of the "Active suit" could lead to the following conclusions:

-The technical reliability, safeness, durability and fidelity (of programme realization) of the whole system proved to be quite satisfactory.

-The present weight, property of autonomy and simplicity of operation and maintenance led to the first trials with absolute self-use by the patient.

-The plan of further development of the preceding model of the "Active suit" (7), promised at the occasion of the preceding meeting has been fulfilled.

At the end should be repeated, that the performances of this type of active orthosis for lower human extremities do not possess the property of stability maintenance, which excludes from the selection of the handicapped persons to be rehabilitated by means of this type of active orthotic side, the paraplegics and similar patients. Nevertheless, the broad array of handicapped persons of the generally called "distrophic” type offer great opportunities for the application of the "Active suit".

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