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ORTHOTIC MECHATRONIC DEVICE

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Abstract: This paper is based on the development of a orthotic mechatronic device, destined for the assistance of the locomotors function at old people with severe disabilities and patients with cardio-respiratory and/or sever neuro-locomotors deficiencies, ensuring the conditions for biocompatibility, stimulation of the blood circulation in the lower limbs and for the thermo - physiologic and sensory comfort and a reduce energetic consume. Are jointed together in **a new unitary conception**, the elements of o mechatronic orthotic structure gifted with actuation systems with reduce energetic consume, with elements that assure the biocompatibility conditions and for thermo physiological and sensorial comfort and with a command equipment for the principal locomotors functions in conformity with special programs pre-established, manual selected by the assisted person.

1. GENERALITIES:

The re-establishment / recovery more completely of the neural functions, first of the neuro-motors so of the autonomy and in this way of the quality of life at paralyzed people and at old people with severe disabilities, means the main objective and the hardest interdisciplinary challenge for the various medical areas and for medical recovery.

For the persons with intellectual jobs, paraplegias and hemi paresis (if is not with aphasias or/and psychic tumults) are compatible with socio-professional reinsertion. There are, also, some accommodations of the residence, of the working place and, into a large plan, of the all socio-urban ambient by accomplishing some permissible slopes/ramps for the rolling armchair access into public buildings, public transportation, on the footway and of some appropriate elevators.

One of the biggest challenge of the humanity at the beginning of this millenary is *the demographic ageing process, in a alert rhythm, at a mondial level,* in case of the old people percent (60 /65 years old and over that) is reach, in the present, in many countries – including Romania – by a fifth, and like a prevision, at a world level, is estimating that the old people will be almost 25%, in the next two decade, mostly in the developed countries, where, in generally, they are the most "demographic oldaget". Demographic ageing is in correlation with the mean life time increasing in the most developed world countries (Japan, Sweden, Switzerland etc.).

Pursuant to the mentioned demographic facts, the groups of the" big old people" is increasing, numeric and like percent (75/80 years old and over that), this demographic group is starting to be important the mini group of the centenarian which by important politapology and increased level of polidisabilities (neuro – mio – artro - kinetic, cardio-vascular, respiratory, sensorial) present a maximum potential that will be beneficiary of some assistive orthotic systems in order to maintain tne functional autonomy and also their quality of life.

Starting from 2005-2006, in more excellence centers, on world plan (Australia, England, Israel, Germany, China, India, South Korea, New Zeeland, SUA etc.), there was started clinical studies for *regenerative medicine*, with three combinative therapies for recovery in the pathology fields, but the results from this moment don't allow the current utilization at the human, in the hospital, of some effective neuro – curative therapies. In

these conditions, the progresses in electronics, informatics and robotics fields, from the last two decade, they are accomplishing some functional assistive orthotic systems, central neuromotors and complex peripheric, which are performant and in miniature, which they could take place of sensibility, command and answer deficit.

Such devices / complex systems could represent an extreme modality for increasing their quality of life and in the same time an important way to reduce the high costs for medico – social attendances of healthy budget, for two million paraplegic and tetra paraplegic people and from all world (and also for some million serious hemiplegics – regarding a mid-frequency by 0,8 %, from general population of the cerebral vascular accidents), and also for some ten thousand of person with mobility sever incapacities from all pathology categories from Romania.

2. CURRENT ACCOMPLISHMENTS IN THE FIELD, AT NATIONAL IN INTERNATIONAL LEVEL

The concerns regarding the accomplishment of some auxiliary devices (assistive) for othostatism and gait is over then half century, or even more.

This concerns has two difrent origins – motivations:

- the absence adjustment / substitution of nervous control at the inferior limb (in principal for paraplegias and in some cases for hemiplegics);
- increasing the motor capacities os some healthy people by using some devices (for examples, soldiers with a fight capacity increased).

The main devices which are for the both goals are the “long” orthoses, for hip, knee, ankle and foot, known like:

- “HKAFO” (Hip – Knee – Ankle – Foot Orthosis);
- ”Exoskeleton” (“robotized” variance, which means mechanical – cybernetic control, in different degrees, of the orthostatism and the gait).

It would be expected that the second goal shuld be reach more quickly, because it is better financing – at least theoretic – more easy: healthy people need only the own force potential helped by some long ortheses, because their neurological functions are normal.

However, in a surprising way, the functional models which are used “in serial” of these devices are not yet on the mark. In 1999, the Military Agency for Advanced Research Projects (DARPA) from SUA, it started a study named: ”Exoskeletons for Human Performances Augmentation” (EHPA), which was finished in 2001 with some results which are not published yet, but they are shown (fig. 1), which appeared in 2004.

The robotized orthotic device, for the inferior limb, allows the improvement of the segmental motors performances, and also for the general physic performances of the healthy person, with applications for increasing the faith capacities of the soldiers who are concerned urban guerilla actions, and for workers who are developed works in isolated areas or hard to reach.

Building some robots with possibilities for orthostatism, gait and recovery like biped, humanoid is a distinct direction for research – development, but more in more convergent, in the last decade, with the theme which we are developed.

At the end of the last millennium and in the last four years, the anthropoid robotic has registered impressive progresses, it was seceded the accomplishment of some biped robots with performaneces for orthostatism, gait, active equilibrium and recoveries, very approach with the human performaneces (Honda – Asimo – 2000 firms, fig. 2, and Sony – SDR – 2003, and also the Institute of Automatic Control Engineering of Technical University of Munich – Johnie - 2003).

Because of the new technological solutions for “control postural” the humanoir robot model “ASIMO” for the last generation, which was set on market in decembre 2004, is able to “run” with a speed by 3 km/h. The maximum ”performance” which is obtain on the present in orthostatism and gait for paraplegia field, are the long ortotic devices like ARGO (Advanced Reciprocating Gait Orthoses), (fig.4), which are equipped or not, function of answers capacities at musculature electro stimulus of some paraplegic, with mobile devices for functional electrical stimulation (FES).

Fig. 1. Robotized orthotic device for the inferior limb

Fig. 2. Humanoid robo t– ASIMO made by HONDA

A advanced accomplishment in the robotized orthoses field is Hybrid Assistive Leg (HAL) – 3, which is accomplished by a collective managed by professor Yoshiyuki Sankai from Tsukuba University, Tokyo – Japan in 2003, (fig. 3), with ulterior developments till HAL – 5 model, which is used like amplifier of the assisted person forces. The most recently accomplish in the robotized orhtoses field is the robotized suit ReWalk™ made by Argo Medical Technologies Ltd. from Israel, (fig. 4).

Fig. 3. Hybrid Assistive Leg (HAL – 3) – Tsukuba, Japan – 2003

Fig. 4. ReWalk™ – Argo Medical Technologies Ltd. – Israel – 2008

3. OUR STRATEGY REGARDING THE REALIZATION OF A ROBOTIC ORTHOTIC SUIT:

From the descriptions analyses of some representative robotic orthotic structures made by a variety of companies, it resulted the necessity of some improvement both on conceptual plan and functional plan, for which aren't yet found the most adequate functional and constructive solutions. We considered that a robotic orthotic structure, in order to be really functional and useful for assisted persons, must satisfy the next conditions:

- wieght and dimensions as reduce as possible,
- the wearing of the robotic orthotic structure under the clothes of the assisted person,
- easy ways for dressing/undressing,
- safe and commode position of the assisted person relative to the robotic orthotic structure, both during non-moving and walking,
- self realization of the main locomotors functions through a simple and commode procedure of the desire movement by the assisted person
- the assurance of the biocompatibility conditions,
- the stimulation of the sanguine circulation, especially that one for venous-lymphatic coming back
- thermo-physiologic and sensorial comfort at the level of locomotors system segments,
- low energetic consumption and low weight and dimensions actuators,
- automatic keeping of the ortostatism in non-moving and walking,
- automatic redressing of the robotic orthotic structure when disturbing factors appear,
- easy adaptation of the robotic orthotic structure to the variety of disability degree,
- simple procedure of training for robotic orthotic structure using,
- low costs.

Taking in consideration the multidisciplinary aspect of the researches in the area of assisted orthotic structures, it was made a interdisciplinary scientific consortium made of SC ICTCM SA Bucharest, Fundatia Prof. Constantin Popovici, S.C. INCDTP–CERTEX S.A., S.C. ICPE SA Bucharest, INCDMF Bucharest, UPB–OPTIMUM, SCUBA, S.C. COMPOZITE S.R.L. Brasov.

In the **first stage**, the researchers were concentrated upon the experimental model of a mechatronic orthotic device in order to allow the studding of the next aspects:

- constructive and functional aspects of the main modules of the supporting structure,
- the realization of some actuators that are specific to the working condition, (low weight and dimensions, high power and efficiency, max. 10ºC overheating),
- the research of the realization principles of the main locomotors functions for movement sagittal plan (going up from the chair, going down on the chair, forward movement, going up and down on the stairs, going up and down on the slopes),
- the realization of the equipment and command programs of the main locomotors functions,
- the realization of the main modular components of a robotic orthotic structure and the research of their functional and constructive aspects, both for mechanical components and for those components that assure the biocompatibility conditions with assisted person,
- the realizations of some testing stands for testing the mechatronic orthotic device.

In the **second stage** of the research, the mechatronic orthotic device was equipped also with spatial hip articulations, thing that allowed the studding of the next aspects:

- spatial movement, on a plan surface, by the realization of returning with variable angels,
- the mechatronic orthotic device equipment with sensors for the realization of the automatic control of the ortostatism and of its redressing at accidental disturbing factors,
- the automatic realization of the orthostatic in stationary regime and during movement in sagittal plan,
- automatic redressing of the orthostatic position at the apparition of disturber factors,
- the comprehension in the main locomotors functions of the new studied functions,
- the command possibility with the help of voluntary brain motor biopotentials of some extra body driving systems for the realization of the main locomotors functions,
- the possibility of using of some materials made of electroactiv polymers for the driving of the supporting structure modules of the robotic orthotic suit, solution of great future in the realization of robotic orthotic suite which will be wear under clothes

In the **third stage** of the researches was made a robotic orthotic suit that has:

- modular supporting structure that can be wear under clothes
- all components are miniaturized, and are a part of supporting structure,
- the automat realization of the ortostatims, both in non-moving regime and walking regime, for movement in sagittal plan or in space,
- the automat redressing of the orthostatic position at the appearance of some disturber factors both in non-movement regime and walking regime,
- the programs perfection of the main locomotors functions for independent movement in space of the assisted person.

4. THE REALIZATION OF THE EXPERIMENTAL MODEL OF A MECHATRONIC ORTHOTIC DEVICE DOM:

The experimental model realization of a mechatronic orthotic device DOM and its components (see TABLE 1) is the main objective in the future development of a robotic orthotic suit capable to assist the orthostatic recuperation and the walking of the persons that have paralyses or/and the older that have severe disabilities with cardio-respiratory insufficiency and/or sever neuro-locomotors problems and it is a research objective of a project within Excellence National Program VIASAN by an interdisciplinary scientific consortium made of SC ICTCM SA Bucharest, as the project coordinator, Prof. Constantin Popovici Foundation, S.C. INCDTP–CERTEX S.A., S.C. ICPE SA Bucharest, INCDMF Bucharest, UPB–OPTIMUM, SCUBA, S.C. COMPOZITE S.R.L. Brasov, as partners.

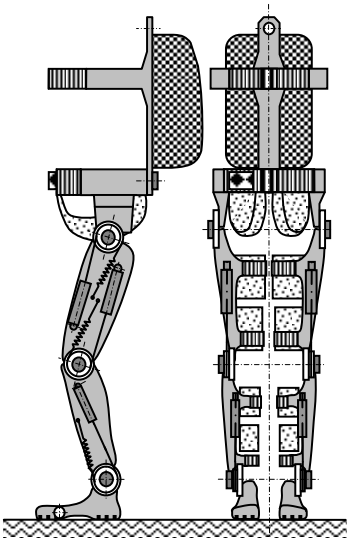
TABLE 1

Experimental models of DOM	
Experimental model	Project manager
Orthotic device DOM	ICTCM
Modular supporting structure of DOM	COMPOZITE
The compensation of the DOM segments weight	ICTCM
Optimized solutions for driving	ICTCM & ICPE
Optimized solution of interaction with assisted person teguments	INCDTP
Ameliorated solution of the venous-lymphatic coming bake circulation	INCDTP
Equipment with sensors DOM	INCDMF
Command equipment of DOM	UPB – OPTIMUM

Stand for experimentation DOM	ICTCM
Stand for adjustment of dynamic parameters	ICTCM
DOM Electrical installation	ICTCM

Made for the locators functionality assistance of the people that have paralyses or/and old people with cardio-respiratory insufficiency and/or sever neuro-locomotors problems, the robotic orthotic suit assure all the conditions of biocompatibility, of sanguine circulation stimulation at the inferior members, of sensorial and thermo-physiologic comfort, low energetic consumption.

CARD 1 – MECHATRONIC ORTHOTIC DEVICE (D.O.M.)



Research objectives:

Orthostatic and walking assisted / recuperation of the old people with severe disabilities and sick people with cardio-respiratory insufficiency and/or sever neuro-locomotors problems

Original solutions are during patenting:

- Integrator concept of the robotic orthotic suit, that won GOLD MEDAL at the International Fair for Invention – Geneva 2008,
- Command equipment and programs for the command of the assistive orthertic devices.

Ways of using as separated products:

- Command equipment and programs for the command of the assistive orthotic devices,
- The assistance of the sick people walk, people that have cardio-respiratory insufficiency by "watching" the movement made and the amplitude of the forces made by the assisted person (see Table 2).

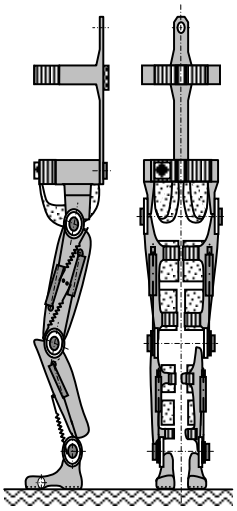
Taking in consideration the systemic and unitary character in which was made the project of the conceptual model, the mechatronic orthotic device components have many elements that are new because of in the paper will be prezentated only data regarding the research objective, original solutions that are during patenting, as well as possibilities of manufacturing and using of some constructive solutions as separated products.

TABLE 2

THE COMPLEXITY OF THE COMMAND EQUIPMENT ACCORDING AS THE DISABILITY DEGREE OF THE ASSISTED PERSON

Healthy person	Person with persoana cu cardio-respiratory disability	Person with easy neuro-locomotors disability	Person with sever neuro-locomotors disability
Without command equipment and without engine and energy source, in case of a passive compensation of the orthotic structure segments weigth and energetic re-equilibration of the movement cycles.	The actuators command, according to some programs tips, is made by computer, their selection being initiated by the sensors that are placed in the interior of the orthotic structure, driving by the movement trend of the locomotors device segments of the assisted person		The actuators command, according to some programs tips, is made by computer, their selection being initiated by assisted person by selection and driving by this person of some buttons, specific to the chosen program.
The actuators command is made by watching (with the help of sensors) the movement the locomotors device segments of the assisted person from the interior of the orthotic structures, the command system being only a self watching system.			

CARD 2 – MECHATRONIC SUPPORTING STRUCTURE



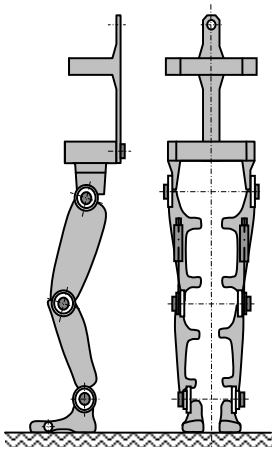
Research objectives:

The realization of some programs specific to the main locomotors functions in sagittal plan: going up from the chair, going down on the chair, walking on horizontal surface, going up and down on the stairs, going up and down on the slops.

Original solution under patenting:

Driving mechanism of the segments articulation of a assistive orthotic device

CARD 3 – MODULAR COMPOSITE STRUCTURE



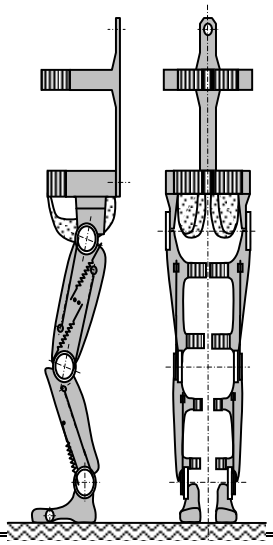
Research objectives:

Compatibility with anatomic particularities of the assisted person and with mechanictronic supporting strucutre

Original solution under patenting:

- Complex assistive supporting structure, with integrated articulations in composite materials,
- Rotation clutches with integrated rotation parts in the supporting structure.

CARD 4 – EQUIPMENT FOR SELF WEIGHT COMPENSATION



Research objectives:

Mechanisms for the recuperation of energy that was consumed during ant gravitational movement

Original solution under patenting:

- Passive mechanism for the recuperation of energy that was consumed during ant gravitational movement,
- Method and assistive dispositive for reducing the physical effort of walking at sick people with cardio-respiratory insufficiency

Possibility of using as separated product:

Passive assistive device for reducing the physical effort of walking at sick people with cardio-respiratory insufficiency

CARD 5 – OPTIMIZED SOLUTIONS FOR DRIVING

Research objectives:

Electrical actuators with low dimensions, weights and overheating for driving DOM modules

Original solution under patenting:

- Linear electrical actuator for DOM driving
- Screw with nut with balls
- Planetary reducer with balls

Possibility of using as separated product:

- Electrical engines with rotor ax that is drilled,
- Linear electrical actuators,
- Screw with nut with planetary roles / nut with balls,
- Planetary reducer with balls

CARD 6 – INTERFACE CU CONTACT AREAS TEGUMENT OF THE ASSISTIVE PERSON

Research objectives:

Biocompatible material which assure thermo-physiologic and psihosenzorial comfort of the assistive person

Original solution under patenting:

Optimized solutions of interaction between the internal face of some assistive devices and the teguments of the contact areas for the persons with neuro-locomotors disabilities

Possibility of using as separated product:

Modulated underclothes system made of microfiber with enlarge elasticity, bioactive, with enlarge comfort made of: seamless brief, trousers socks, cochain type, socks.

CARD 7 – SOLUTION FOR AMELIORATION OF THE VENOUS-LYMPHATIC CIRCULATION

Research objectives:

- The realization of discontinuous pressure, under the form of peristaltice waves,
- The optimization of the teguments airing of the assistive person,
- Contact pressure uniformization and reducing

Original solution under patenting:

- Equipment for the amelioration of the venous-lymphatic coming back circulation for persons with disabilities
- Pillows and cushion made with massage possibilities

Possibility of using as separated product:

- Equipment for amelioration of the venous-lymphatic circulation,
- Pillows and cushion made with massage possibilities

CARD 8 – EQUIPMENT FOR SENSORISATION , AUTOMATION AND COMMAND

Research objectives:

- Manual command for programs specific of the locomotors device: going up and down on the chair, walking on the surface, going up and down on stairs and prone plane
- Information regarding the pressure repartition on foot, temperature and humidity of teguments
- Program for testing the electrical accumulator.

Original solution under patenting:

Command bloc of the equipment for amelioration of the venous-lymphatic coming bake circulation,

Possibility of using as separated product:

On request equipment for amelioration of the venous-lymphatic coming bake circulation

CARD 9 – COMMAND EQUIPMENT OF THE MAIN LOCOMOTORS FUNCTIONS

Research objectives:

Electrical actuators command for the realization of the main locomotors functions for movement in sagittal plan,

Original solution under patenting:

Method of programming, soft and equipment for the command of main locomotors functions of a mechatronic orthotic device for persons with neuro-locomotors disabilities

CARD 10 – STAND FOR EXPERIMENTATION OF THE MECHATRONIC ORTHOTIC DEVICE

Research objectives:

- The determination of the kinematic parameters of the main locomotors functions for movement in sagittal plan,
- The realization and testing of the specific programs

Original solution under patenting:

- Equipment for the determination of the kinematic parameters of the main locomotors functions for movement,
- Equilibration device

Possibility of using as separated product:

- Research equipment,
- Equipment for kinetic – therapy

CARD 11 – STAND FOR ADJUSTMENT OF THE DYNAMIC PARAMETERS OF THE ACTUATORS

Research objectives:

- The determination of the kinematic parameters of the main locomotors functions for movement in sagittal plan,
- The realization and testing of the specific programs

Original solution under patenting:

- Adjustment of the dynamic parameters for the actuators of each articulation type, independently and for the entire assembly,
- Testing and optimization of the programs for main locomotors functions

Possibility of using as separated product:

Research equipment

5. CONCLUSION:

Within this paper are represented the main components of the experimental model of the mechatronic orthotic device, the functional role of those, the main specific research objectives, as well as some original solution, that were found up to this stage of the project, for a part of them being under development the documentation for intellectual property. It is also represented, the components of the mechatronic orthotic device that ca be used as independent product for the treatment of some circulatory affections of the locomotors device, as well as a series of original constructive solutions which can be used as independent products in other industrial areas.

According to the strategy taken in consideration for the realization of the mechatronic orthotic device, it is appreciated that a wide area of researches will be opened in the high performance actuators areas – that are near the moment of crossing from research to wide range using – made from “intelligent” composite materials (electroactive polymers, materials that have form memory etc.), complex supporting structures with sensors from composite materials with incorporated kinematic clutches, command equipements and miniaturized energy sources, research objectives which will drive to the realization, in future, of a robotic orthotic suit, that can be used in clinical activity and in day by day professional and social life by persons with cardio-respiratory insufficiency and / or neuro-locomotors deficiencies.

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