NEW CONCEPTS IN EXTERNAL POWERED ARM COMPONENTS

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INTRODUCTION:
An electrically powered joint can be of considerable support for many unilateral or bilateral above elbow amputees in every day activities. The DynamicArm (Photo 1) represents the next evolutionary step, a milestone in powered elbow prosthetics. It has been designed around previously proven components and also adds new developments that will change the way the amputee interacts with the prosthesis. Multiple control strategies and inputs running in parallel as well as hardware that allows for a more natural operation with much less effort will heighten the level of expectation from every patient wearing this design. This is already the case based on the response of the patients that have been fitted so far. Patients who have had many years experience with powered systems or those who have had experience with hybrid systems report the decrease in mental and physical energy within moments of being fit. Repositioning exercises, switching between components and actively controlling each component seem to be done with ease. Some of the advantages for the amputee are rapid movement and pre-positioning. This allows the patient to lift higher weights and position the elbow without complex control sequences. Because pre-positioning is more easily facilitated the patient will chose to move the component rather than make up for some controllability deficit with a compensation movement of the trunk. High loads can also be held in position without fear that something will be damaged if it is overloaded thanks to the already known locking mechanism of the 12K50 ErgoArm. Built in force sensors protect the system from unlocking in undesirable conditions. The control characteristics follow those of previously designed components like the DMC+ and the SensorHand Speed. Otto Bock electronics follow the logic of „First Signal Wins“ control strategy but a new improvement allows for fast changing between opening and closing the hand or changing from flexing to extending or from supination into pronation. This gives the advantage of being able to fit the patient who co-contracts but still allows for high performance controls. Signal inputs are now digitized by the locking microprocessor and from there are not as susceptible to Electromagnetic Interference. Power consumption
has been reduced because when the system is in free swing, the mechanics are completely
de-coupled from the movement of the Automatic Forearm Balance mechanism. New
possibilities of control include being able to raise and lower loads at various speeds and
repositioning without needing to produce an “unlock” signal. The wrist rotator is
controlled by the main electronics which allows for an ultra sensitive control and the
possibility to run the wrist motor proportionally and at incredibly low speed allowing for
very precise positioning. The terminal devices as before can be controlled with
proportional speed and grip force based on the strength of the muscle signal which is
supported by having the electronics combined with the hand mechanics. Simultaneous
control of the hand and the elbow with using a variety of input devices is now possible.
And now for the first time new input devices and new switching methods allow for more
flexibility for the amputee to control the prosthesis.

TECHNICAL DATA:
- LiIon battery 1900 mAh internal
- 268°/sec full ROM in 0.5sec
- 960g overall weight of the elbow without hand
- Maximum live lift of 12lbs
- ROM 15° - 145°
- 4 Microprocessors with Axon Bus® technology
- Max load = 50ft/lbs

The mechanics are built around the known AFB mechanism which is at its core. The
frame of the AFB is constructed of Aluminum to aid in dissipating heat generated by the
lifting motor.

LIFTING MOTOR:
The lifting motor is a flat brushless disk motor that was designed
by Otto Bock Vienna. It has a high torque moment with a flat
construction which makes it light weight and takes up little
space. Without brushes means it has a very high life cycle and
with the synthetic rotor it allows for a very low
inertia for a quick start of the motor. A specially
cover is designed with cooling fins since the spool
creates a lot of heat. Overheating is protected by monitoring the temperature with a
sensor which shuts down the system if the temperature rises above 80 degrees Celsius.

VARIO-GEAR
The DynamicArm also introduces a new concept in transmission
controls for powered elbows with the Vario-Gear (Illustration 1)
continuously variable transmission. It is a miniaturized design based
on those that were used in large printing presses. The gear ratio can
be adjusted between 2:1 to 18:1 based on the input from the force
sensor built into the forearm and the control input signal generated
by the patient. When the DynamicArm senses a load the Vario-Gear seamlessly adapts to avoid any abrupt movement for precise controlled lifting. With this Vario-Gear the drive and the output can be completely decoupled which allows for free swing with natural movement that does not consume precious battery power and is very quiet. The Vario-Gear is driven into position by a Servomotor which is controlled by the motion processor in the main electronics. Again based input from the force sensor and the control inputs from the patient, the servo-motor positions the Vario-Gear for correct operation and is adjusted 100x per second. Central to the Vario-Gear and the lifting motor is the Automatic Forearm Balance mechanism. This well known concept has various levels of compensation based on the exact flexion angle. In complete extension it compensates very little which is another reason that free swing functions the way it does and as the arm is flexed the compensation increases until approximately 90 degrees when the compensation again decreases to prevent uncontrollable acceleration to full flexion. To engage free-swing the patient must bring the elbow within 15 degrees of full extension and the locking unit will not lock the elbow. In order to relock the elbow at this point the patient only needs to give a small flexion signal and it will lock automatically when the signal stops.

LOCKING UNIT:
The locking mechanism is known from the ErgoArm family of elbows. Its infinite position lock and easy operation make it a natural selection for the DynamicArm. The movement of the forearm and the locking action are harmoniously coupled so that the patient does not need to produce an unlock signal only a control signal to initiate either flexion or extension.

AXON-BUS®

For the first time in prosthetics is the Adaptive eXchange Of Neuroplacement data AXON-BUS® (ill. 2) has been implemented. In this application all components can be communicated with and programmed independently and for minimized EMI, automatic recognition of the connected components and for automatic error recognition.

ELECTRONICS:
The electronics include a combination of 4 microprocessors; the lock processor with the analog to digital signal converter, the signal processor which controls the AXON-BUS®,
gets input from the sensors and controls the Bluetooth interface, the motion processor which controls the lifting motor, servo-motor and the wrist rotator, and finally the hand processor which is located in the terminal device. The input devices are connected to the Easy Plug connector at the top of the electronics for the elbow lock. This signal is digitized and sent to the main electronics through the AXON-BUS® system and can then simultaneously go to the hand or wrist or lifting motor depending on the chosen control. It does not however need time to be analyzed by each component thus slowing down the signal. There are five sensors in the system including the angle sensor, servo sensor, force sensor, battery monitor and temperature monitor.

CONCLUSION:

The progress in microprocessor and mechanical technology allows new possibilities in the design of prosthetic systems. Like in all complex systems there are close interdependencies between all components. Progress in the mechanical part of the system often require further developments in the field of sensory, electronics and software. A significant acceleration in the development of new prosthetic components is the result, bringing us closer to our goal: The improvement of the quality of life for people with disabilities.