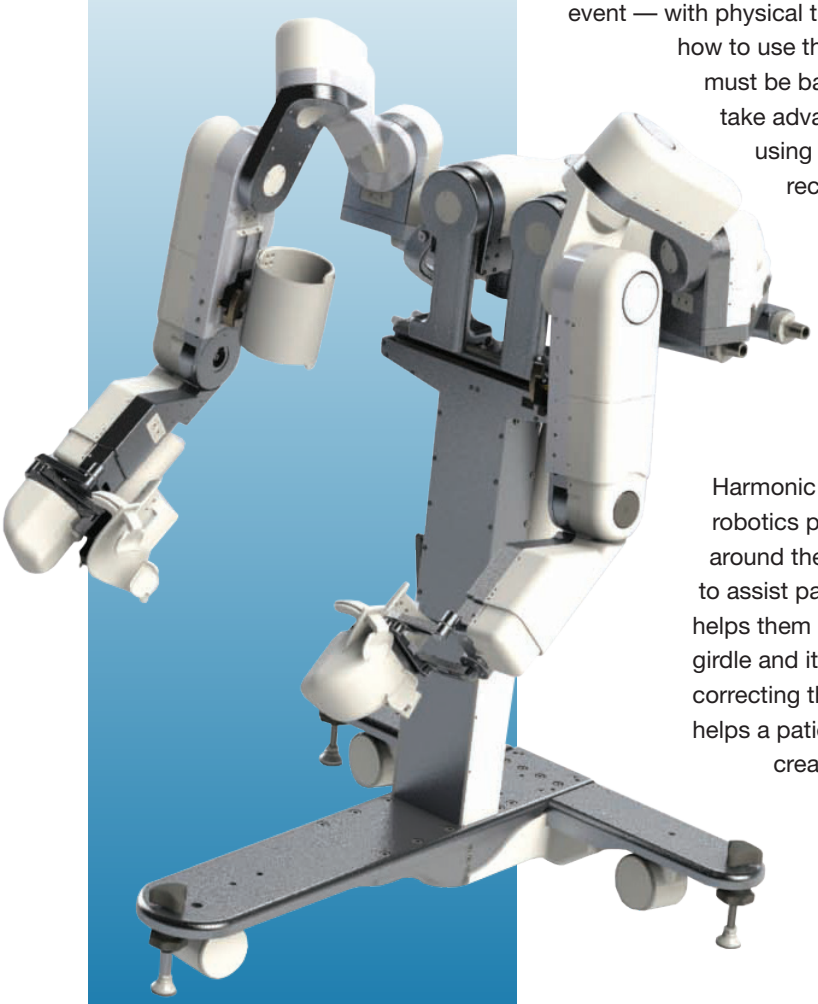
WHITE PAPER

Improving Post-Stroke Rehabilitation:
Crossed Roller Bearings Give Physical Therapy Exoskeletal Robot a Helping Hand

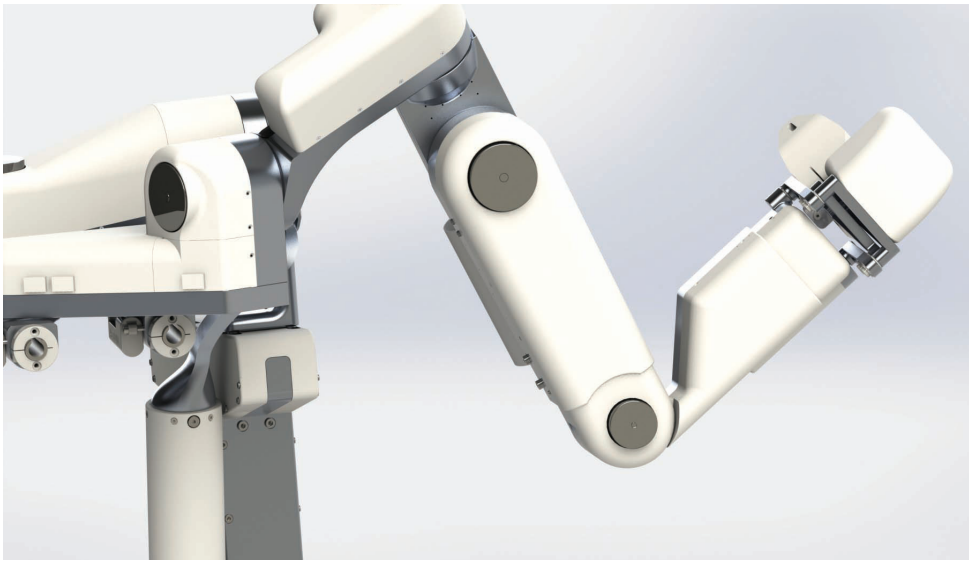
Each year, approximately 700,000 people survive a stroke. As deaths caused by stroke decrease and our population ages, that number is expected to increase by nearly 40 percent over the next 10 years. Most of those survivors will require rehabilitation in order to regain as much independence and quality of life as possible. However, the rapidly increasing demand for post-stroke rehabilitation cannot be addressed through traditional physical therapy means alone.

AN EXOSKELETAL ROBOT IMPROVES PHYSICAL THERAPY OUTCOMES FOR STROKE SURVIVORS



Rehabilitation often begins soon after the stroke — perhaps within a day or two of the event — with physical therapy in the intensive care unit to enable the patient to relearn how to use their limbs that are often paralyzed by the stroke. Effective therapy must be based on the principles of neuromuscular physiology and can often take advantage of known neurological coupling between human joints, using coordinated movements and forces to boost true functional recovery. Shoulder rehabilitation is regarded as one of the most challenging forms of physical therapy, due to the complexity and range of motion (RoM) of the shoulder, which poses a significant obstacle to traditional forms of therapy. A newly developed exoskeleton — called Harmony — is designed to precisely address these challenges by creating a highly sensitive and repeatable platform which can greatly improve the effectiveness of shoulder therapy for stroke survivors.

Harmonic Bionics was founded in 2016 to develop innovative rehabilitation robotics platforms for the clinical market. Their Harmony exoskeleton wraps around the patient's shoulders, arms and wrists and can power their joints to assist patients as they perform various dynamic movement tasks. This helps them relearn the specific rhythm that happens between the shoulder's girdle and its ball and socket joint to maximize range of motion, thereby correcting the impaired neuromuscular function. Whereas a physical therapist helps a patient move their arm and observes the movement, the exoskeleton creates an assist-as-needed paradigm that encourages active patient participation and frees up the therapist to massage the arm or even monitor multiple patients at once. The platform intends to promote better, more effective healing and improve outcomes for both the patient and the hospital.



The main arm of Harmonic Bionics' exoskeleton. IKO crossed roller bearings help the exoskeleton move coaxially when a patient moves their arms.

The company traces its origins to research at the ReNeu Robotics Lab at the University of Texas (Austin) Cockrell School of Engineering in 2011. Since then, the rehabilitation robot has received funding and support from NASA and the National Science Foundation (NSF) under many headings including the Small Business Innovation Research (SBIR) program.

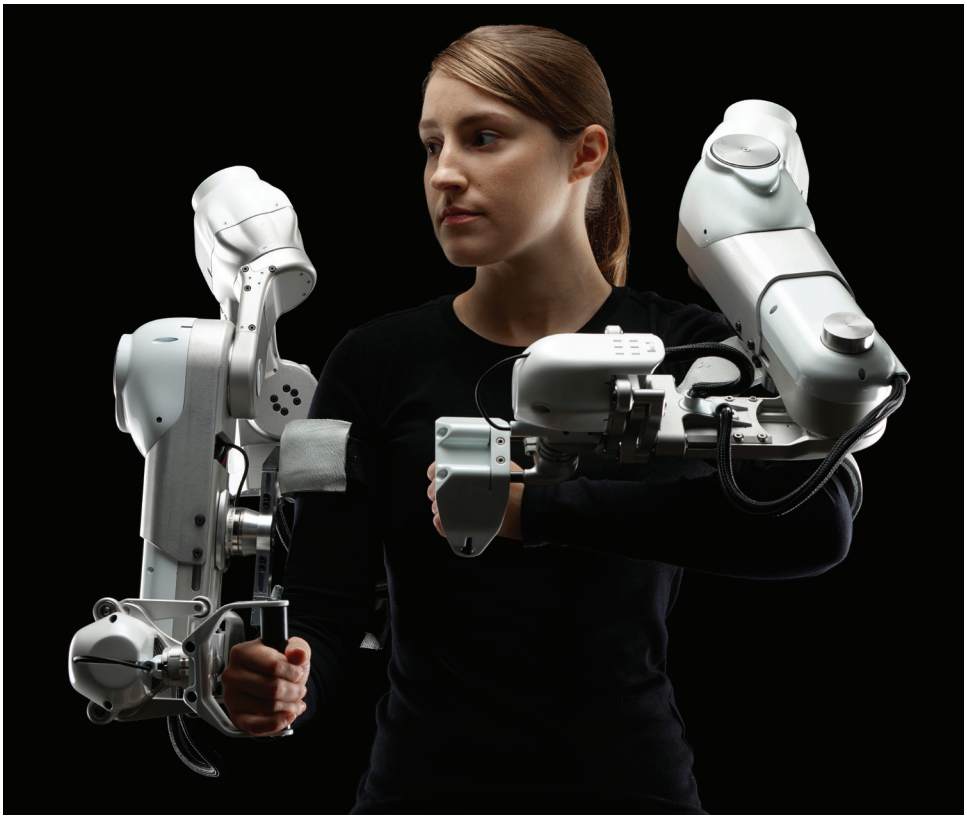
The rehabilitation robot uses advanced actuator technology and a suite of sensors that collect motion data, at a high speed of two kilohertz, which is fed into an algorithm to give users responsive control of varying levels of resistance during exercises. The designers needed a roller bearing that could carry large moment loads so the exoskeleton can move coaxially with the patients' skeletal structure as they move their arms. This enables bimanual therapy which takes advantage of a proven neurological coupling of the left and right halves of the human nervous system to aid recovery. The bearing also needed to be small, lightweight and offer a low coefficient of friction (CoF).

As Rohit Varghese, the Head of Product Development at Harmonic Bionics recalled, the choice was clear: IKO International's CRBH and CRBF crossed roller bearings. "An exoskeleton like ours has very unique challenges," Varghese said, referring to the robot's load requirements and limited space. "Very few bearings can satisfy them. IKO's CRBH and CRBF crossed roller bearings fit very well."

CROSSED ROLLER BEARINGS CARRY HIGH MOMENT LOADS TO ASSIST PATIENTS AND THERAPISTS

IKO's crossed roller bearings are both compact and rigid, making them well-suited for robotics and medical equipment. With rollers alternately crossed at right angles between inner and outer rings, they can handle radial, thrust and moment loads at the same time with high rotational accuracy. CRBH crossed roller bearings are available with basic dynamic load ratings ranging from 2,910 to 102,000 newtons, basic static load ratings from 2,430 to 207,000 newtons and shaft diameters from 20 to 250 millimeters. The series also boasts:

- An inseparable design that integrates the inner and outer rings into one structure for high rigidity.
- Separators between cylindrical rollers which ensure smooth rotation even at high rotational speeds.



Harmonic Bionics' upper-limb exoskeleton improves the clinical efficacy and productivity of physical therapy for stroke rehabilitation. With the help of IKO crossed roller bearings, the exoskeleton can power the movements of both sides of a stroke survivor's body, enabling novel physical therapy techniques.

Harmonic Bionics chose a model with basic dynamic load rating of 8,610 newtons and basic static load rating of 10,600 newtons — more than enough load-carrying ability to meet their moment load requirement of 100 newton-meters. And with a 40-millimeter shaft diameter, 65-millimeter outer diameter, 10-millimeter width and light weight of 0.15 kilograms, the designers had no problem incorporating the crossed roller bearing within the exoskeleton's limited space. Along the way, they received support from IKO engineering and sales managers. "IKO has been great," said Varghese. "The sales team visited our facility along with one of their lead engineers, and we had deep discussions on how the bearing could best be used including some customization for our application."

The company found that the CRBH crossed roller bearing is the most straightforward and compact way to carry the moment loads imposed on the exoskeleton, providing "just enough assistance" to the patient. This is in large part due to the CRBH's low CoF, after necessary modifications. As the rehabilitation robot's more than 50 sensors monitor the positions of the patients and the forces their joints exert, the low CoF allows the system to run the algorithms that customize the levels of resistance and support that the patient receives relative to gravitational forces. High friction can otherwise compromise the sensor measurements.

As the engineers built the prototype robot, they determined IKO's CRBF bearing was a valuable tool in the process. Like the CRBH Series, the CRBF has an alternatively crossed-roller design. It features mounting holes on both the inner and outer rings, so the engineers were able to install the bearing without machining, special housings or fixing plates to the micrometer-level bearing tolerances. The mounting holes saved space and simplified assembly before the company shifted to the CRBH Series for the production units.

Compact, rigid CRBH crossed roller bearings can handle radial, thrust and moment loads at the same time with high rotational accuracy, making them well-suited for medical and robotics applications.

TRANSFORMING POST-STROKE PHYSICAL THERAPY AND SURVIVORS' LIVES

The rehabilitation robot has undergone extensive clinical trials with healthy subjects in addition to pilot clinical studies with stroke patients, and Harmonic Bionics reports that the CRBH is meeting expectations: "We're happy with its performance," said Varghese. "It is holding up." At the same time, the robot is receiving praise from users and the medical community alike. Said one stroke subject who participated in a study, "My arm moves better than ever. The improvement is helping me all the time in my daily activities." And, Varghese also notes that renowned hospitals have flown their therapists to Harmonic Bionics' Texas facility to explore the technology: "They speak very highly of it, and they can't wait to get it." Today, the rehabilitation robot is being readied for production towards FDA certification and clinical use.

Hospitals have long sought a clinical intervention that will lead to better clinical results than conventional treatments for shoulder rehabilitation for stroke survivors. Harmonic Bionics' successful upper limb rehabilitation exoskeleton robot design shows that when a machine must handle large moment loads within a limited space, not all roller bearings are created equal. Thanks to IKO International's CRBH and CRBF crossed roller bearings' combination of high moment load handling capabilities, excellent rigidity, small size and low coefficient of friction, Harmonic Bionics is poised to revolutionize physical therapy and improve the lives of many stroke survivors.

For more information about IKO International's crossed roller bearings for complex loads, visit www.ikont.com/rotary-bearings/crossed-roller-bearings.