Design Evaluation of REMAP Exoskeleton

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***Abstract*— Lower extremity paralysis results in significant global morbidity and mortality. In India it is discovered that 3.96 percent of the population is handicapped. Roughly 1% of the world's population relies on wheelchairs for mobility. There are currently about 262,000 spinal cord injured (SCI) individuals in the United States, with roughly 12,000 new injuries sustained each year at an average age of injury of 40.2 years. Of these, at least 44% (at least 5300 cases per year) result in paraplegia. In an effort to restore some degree of legged mobility to individuals with paraplegia, several lower limb orthoses have been developed.**

To solve the above mentioned issues we have developed an exoskeletal suit that could be worn around the waist till the toe which is driven by actuators that enable the user to maneuver without any external assistance. The design is anthropomorphic and utmost care has been taken to ensure that the biomechanically the system is similar to the normal leg. The overall biomimetic approach towards the design has helped to achieve a perfect synergy between the exoskeleton and the wearer. The elaborated design ideology comes out of six iterative re-modifications.

Keywords— **Paraplegia, Exoskeletons, Design analysis, Anthromorphic modelling**

I. INTRODUCTION

Lower extremity paralysis results in significant global morbidity and mortality. In India it is discovered that 3.96 percent of the population is handicapped. Roughly 1% of the world's population relies on wheelchairs for mobility. [6].There are currently about 262,000 spinal cord injured (SCI) individuals in the United States, with roughly 12,000 new injuries sustained each year at an average age of injury of 40.2 years. Of these, at least 44% (at least 5300 cases per year) result in paraplegia [7]. One of the most significant impairments resulting from paraplegia is the loss of mobility, particularly given the relatively young age at which such injuries occur. Surveys of persons with paraplegia indicate that mobility concerns are among the most prevalent [2], and that chief among mobility desires is the ability to walk and stand [3]. In addition to impaired mobility, the inability to stand and walk entails severe physiological effects, including muscular atrophy, loss of bone mineral content, frequent skin breakdown problems, increased incidence of urinary tract infection, muscle spasticity, impaired lymphatic and vascular circulation, impaired digestive operation, and reduced respiratory and cardiovascular capacities [1].

In an effort to restore some degree of legged mobility to individuals with paraplegia, several lower limb orthoses have been developed. Although wheelchairs play a high role in enhancing paraplegic mobility, the options for people with mobility disorders have been limited. Humans were not designed to sit for hours on end [4]. Constant sitting might lead to pressure sores, atrophied leg muscles and brittle bones. Wheelchair users are at elevated risk for carpal tunnel syndrome or repetitive strain injury from the constant impact of the hands against the push rims of the wheels [3]. To solve the above mentioned issues we have developed an exoskeleton suit that could be worn around the waist till the toe which is driven by actuators that enable the user to maneuver without any external assistance. The design is anthropomorphic and utmost care has been taken to ensure that the biomechanically the system is similar to the normal leg.

II. MATERIALS AND METHODS

A. *Materials and Designs*

The material analysis enabled the selection of proper materials for the facilitation optimized design. Materials are chosen in such a way that it consumes less weight and volume. The identified materials are listed as: Al 2023 is extremely light weight and has high tensile strength it can be fabricated with metal fusion techniques, machinability and it forms the entire exoskeleton structure and rigid casings. (Titanium + Steel alloy) electroplated with Zn or Cr has ability to withstand high shear stress so it can be used for fixtures, fasteners, bolt, nuts and mountings. Cast-iron/Steel is light weight and ideal for power transmission inside the system.

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B. Structural Elements

The entire exoskeleton is a single functional unit. Based on the human anatomy this integrated unit is discrete into the different functional entities. All the attributes of the individual elements are approximated to reach human anthropomorphology

Figure 1 Complete Exoskeleton design

C. Foot and ankle design

This design has one DOF for foot and Knee joint, with 2 DOF for Hip. It has been facilitated to affix the actuators along the sides of the exoskeleton with the joint couples with all functional elements for power transmission, dampers to act as active/passive suspension for ankle joint. Flaps are provided to take large pressure with minimal contact area. This facilitates the absorption or energy during initial contact and releases it during the heel strike. The foot part has a stud connected to a damper that performs this function. Also the materials are carved out without disturbing the structural stability to ensure that the system has low weight. The ankle joint connects the foot part to the lower shank of the exoskeleton; it has all the power transmission elements that facilitate a smooth rotation between the two.

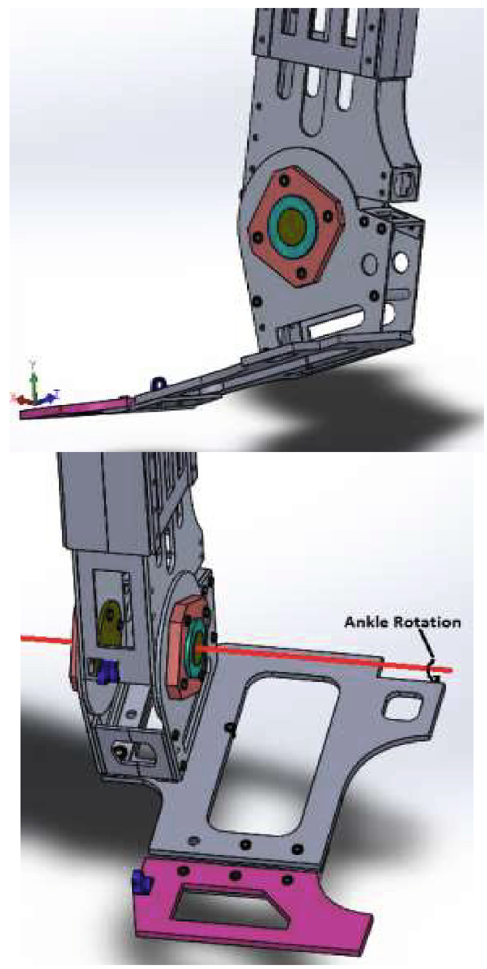

Figure 2: Compliant Foot and ankle Part

D. Shank Part

The shank is constructed out of four sheet metal entities, fastened to form a cubical structure that sides over the other. In the previous designs adjustment of shank according to user height was not possible. But in this design facilitation to adjust to any wearer's height has been provided. The design shows the best possible shank design as a result of iterative adjustments over its former. Joint's motion stoppers provide controlled range of motion. They are designed as mechanical projections over the semi-circular motion path of the two relative parts, when the range of motion ends the motion are constrained by the collision of the projections. Also for safety regulatory stoppers are provided with 35 degrees of flexion beyond which the motion is constrained.

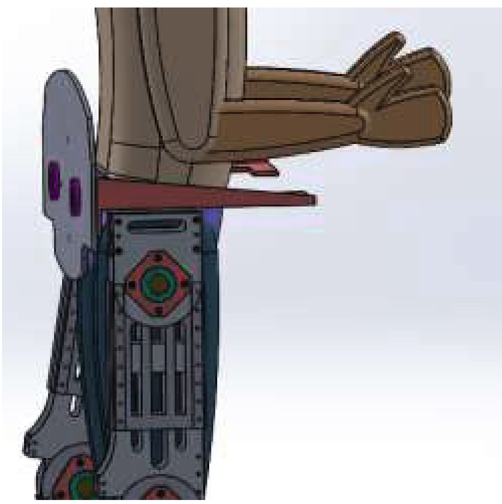

Figure 3: Shank and thigh Part design

E. Knee and hip joint

The knee joint provides relative motion between the lower thigh and upper shank part, by connecting the two using a pin joint. The joint elements include inner coupling, a bearing and a bearing socket that are fastened to the semi-circular edges of the parts. Rugged joint structures are used in the knee joint as it is subjected to the higher torque values. Knee joint is active and is driven by an actuator connected perpendicular to the axis of rotation. Similar to other joints the knee also has motion stoppers that prevent the over flexion and extension within the range of motion. Complex design and functional elements are incorporated into hip joint as it needs to accommodate 3 DOF into a single unit. The hip joint connects the entire lower limb to the hip base via pin joints that can have relative motion between the two. The lower hip part connected to thigh with one DOF which provides the flexion and extension of the lower limb within the range of motion.

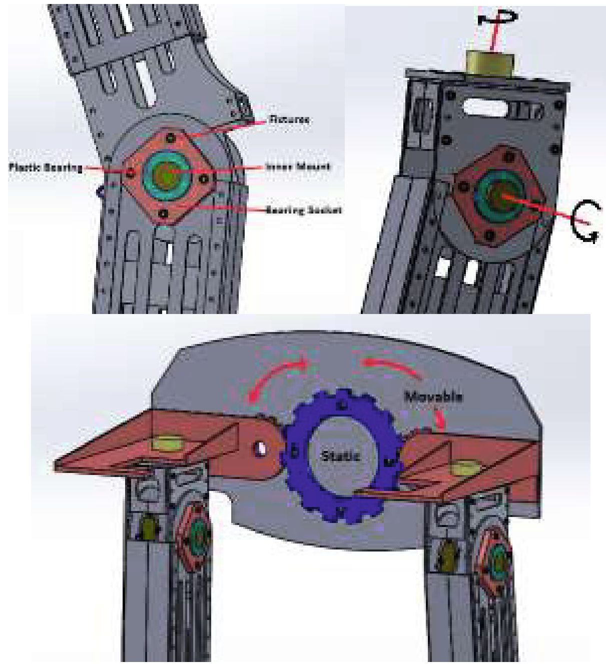

Figure 4: Hip and ankle design

III. CONCLUSIONS

The overall biomimetic approach towards the design has helped to achieve a perfect synergy between the exoskeleton and the wearer. All the joints of the wearer and the robot system lie on the same axis. Straps are provided to adhere the user intact. Also the hip joint accommodates the user comfortability. As this is the preliminary design, more patient comfort levels can be achieved on further alterations over the covers.The elaborated design ideology comes out of six iterative re-modifications. The current design is evident in proving its reliability towards the former designs. Further structural analysis investigates the physical behaviour of a model understand and improve the mechanical performance of a design. Minimizing the size and weight of the structural elements was traded off against maintaining structural stiffness so that the payload could be adequately supported. The strength to weight ratio of the exoskeleton components was maximized using finite element analysis

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

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