Project 1
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EXOSKELETON FOR ASSISTED STAIR CLIMB

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EXOSKELETON FOR ASSISTED STAIR CLIMB

1. INTRODUCTION:

The mobility of individuals is vital to their everyday activities and has been directly linked to their quality of life. Unfortunately, physical difficulties arising from aging, trauma, or diseases often greatly limit the independence of otherwise healthy people. Moreover, fatigue and instability can make locomotion energy-inefficient and difficult over long distances. This problem is more serious for people with limb weakness to climb upstairs. As per WHO reports, every year an estimated global population of 646000 succumbed due to falls, 37.3 million falls are severe enough to require medical attention. Approximately 28- 35% of individuals aged over 65 die due to stair falls and the number has increased to 32- 42% for those over 70 years. Hence researchers are investigating advanced assistance systems to sustain their body posture and augment their motion ability. This mechanism can be used by a larger section of the population as the prototype dimensions can be adjusted in all 3 directions. This device can be improvised for multifunctionality (walking assistance, wearable chair) along with improvements in its assistance torque and ergonomics. Modeling of exoskeleton components was performed using SolidWorks. The present work was aimed at developing a human-operated mechanical actuation device to assist stair-climbing.

2. LITERATURE SURVEY:

Most commercialized powered assisting systems that can be used for human rehabilitation are ReWalk robotics, Ekso bionics, Rex bionics, LokoMat, and many others. In research related to active assisting systems [1], the authors have developed an assisting device (HAL) in the direction of motion assistance and rehabilitation for people with motion weakness. This device has been designed accordingly and experimentally tested. The power units of HAL can produce power assist torque by augmenting the joint torque of the user which is estimated from the user's bioelectrical signals, and the support motions are consequently controlled. This control was used for power assistance of a healthy person's activities, e.g., walking and standing up from a sitting posture. Fatai Sado et al., presented a research paper [2], in which a lower body performance augmentation exoskeleton system for motion assistance based on the user's knee torque amplification was proposed.

The walking assist exoskeleton was built using the concept of generating upward force using the cable and spring arrangement [3]. It is done with the self-weight of the person. The research work by Libo Zhou et al. focused on developing a device that assists in waking as well as climbing stairs [4]. The use of springs in parallel to the thigh and calf muscles connecting at the hip, knee, and ankle. The forward kinematics is calculated using Newton-Raphson method in MATLAB to find the position of the mechanism [5].

Most of the research is focused on powered exoskeleton systems that include ReWalk, Exo Bionics, Hyundai, Berkley, etc. These wearable mobile exoskeletons provide greater limb movement, are expensive, and have limited power range. The novelty of the project is attributed to the development of a passive stair climb assist device operated by a combination of springs and a hand lever. This device will enable economically weak and old age people.

3. MECHANISM:

The mechanism was modeled in SolidWorks and motion analysis was done. Multiple slots were provided to fit all height ranges of people to use this passive assist system. The further model was taken into CatiaV5 for checking with Manikin. The staircase was modeled and tried to simulate the climbing assist system on the stairs.

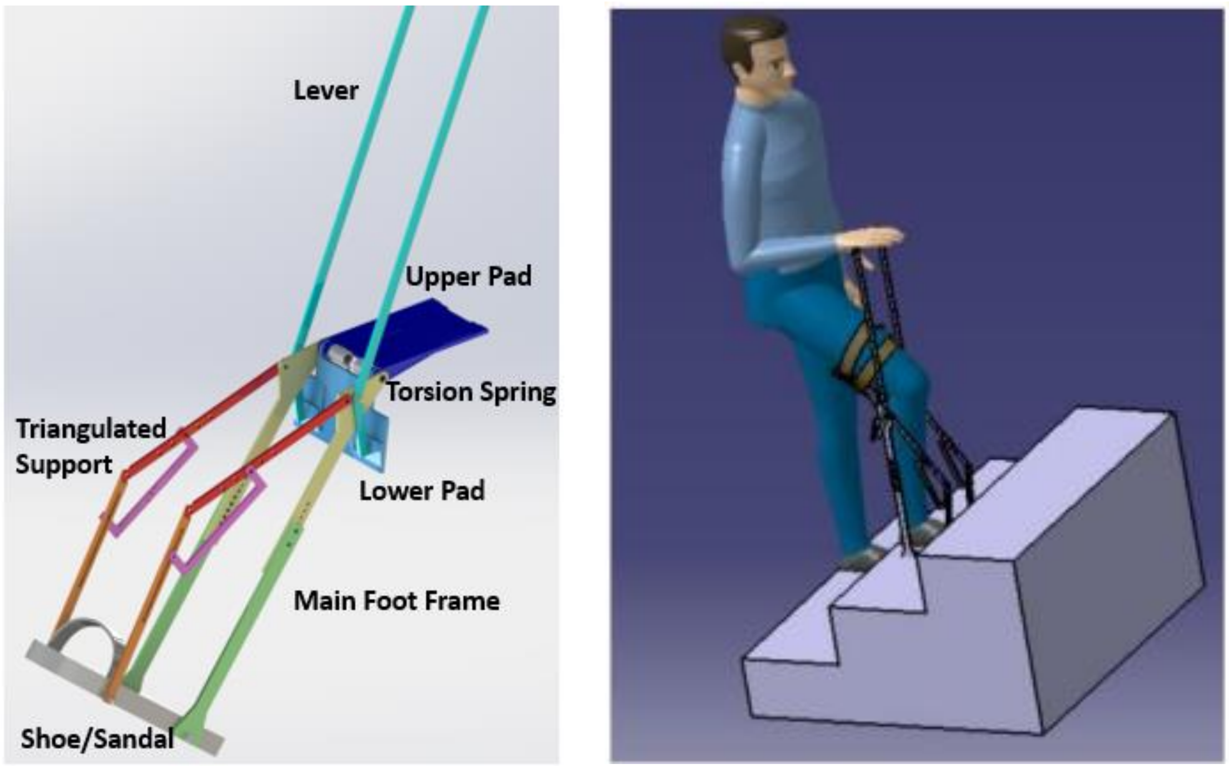

Fig 1- Final model of EXOSKELETON FOR ASSISTED STAIR CLIMB

3.1 Mobility Analysis- Grubler’s Analysis for Degrees of Freedom (DOF):

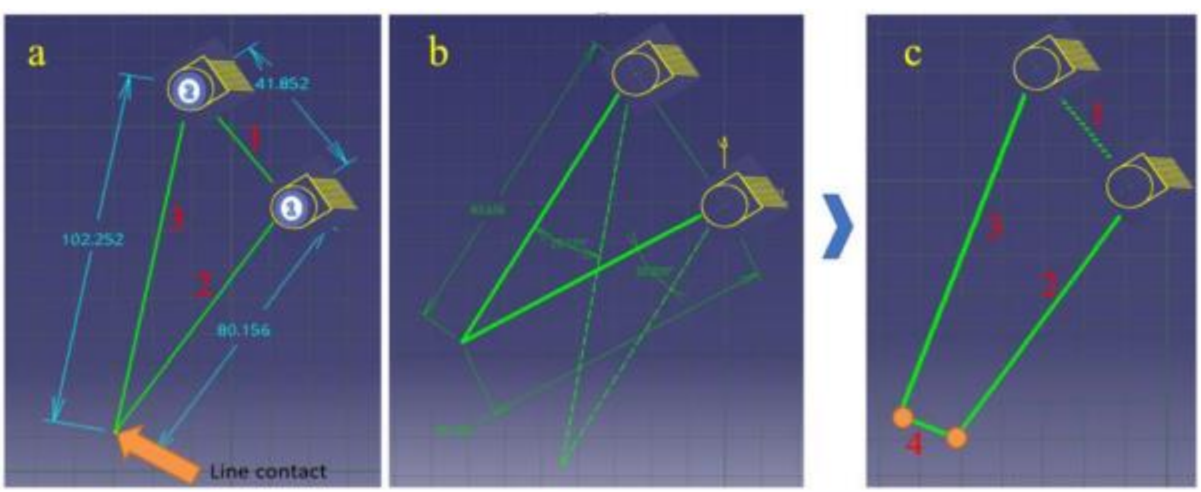

Fig 2 a) shows the line diagram of the assisting system. Revolute joins (1) and (2) depicted by blue circles are the centers of rotation of the lever and the lower pad about main supporting frame respectively. Linkages

(1), (2) and (3) marked in red represent the main supporting frame as ground, shorter arm of lever and the lower pad respectively. There exists a line contact between links 2 and 3 with a higher pair having 2 degrees of freedom. The effective link lengths are also mentioned in Fig 3.1a corresponding to the initial position of the system.

Number of links (N) = 3, Number of Joints (J) = 3, Independent freedoms, ∑Fi= 4, m=3 (Planar)

By Grubler's equation:

DOF = m(N-1-J) + ∑Fi = 3(3-1-3) + 4 = 1

Therefore, the mechanism has a single DOF, inferring that a single input motion to any link will create the defined and constrained motion of other links as related to adjacent links. So, the rotation motion of the lever imparts the constrained and determined motion of other links.

Number of links (N) = 4, Number of Joints (J) = 4, Independent freedoms, ∑Fi= 4, m=3 (Planar)

By Grubler's equation:

DOF = m(N-1-J) + ∑Fi = 3(4-1-4) + 4 = 1

The obtained DOF is 1 and is equal to the earlier DOF of the actual mechanism. The mechanisms shown in Fig 3.2a and 3.2c have different numbers of links and joints but DOF for both mechanisms are the same (single DOF). Therefore, the actual mechanism is an equivalent four-bar mechanism.

3.2 Forward Kinematics: Analytical Method using MATLAB.

Forward Kinematics in MATLAB used the Newton-Raphson method to find the position of the system. Since the link lengths are known, we can calculate the output angle with any input angle.

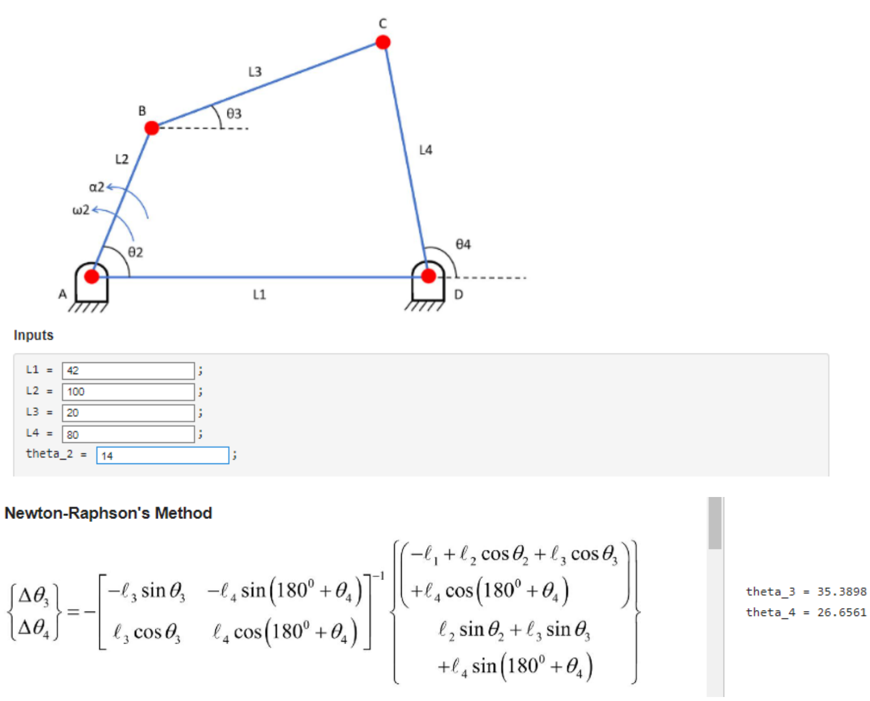

Fig 3: MATLAB snapshot of Four-Bar Position Analytical Solution.

The input angle is 14 degrees in the CW direction, The output angle is 26.6 degrees in the CW direction.

3.3 Forward Kinematics: Analytical Method using SolidWorks:

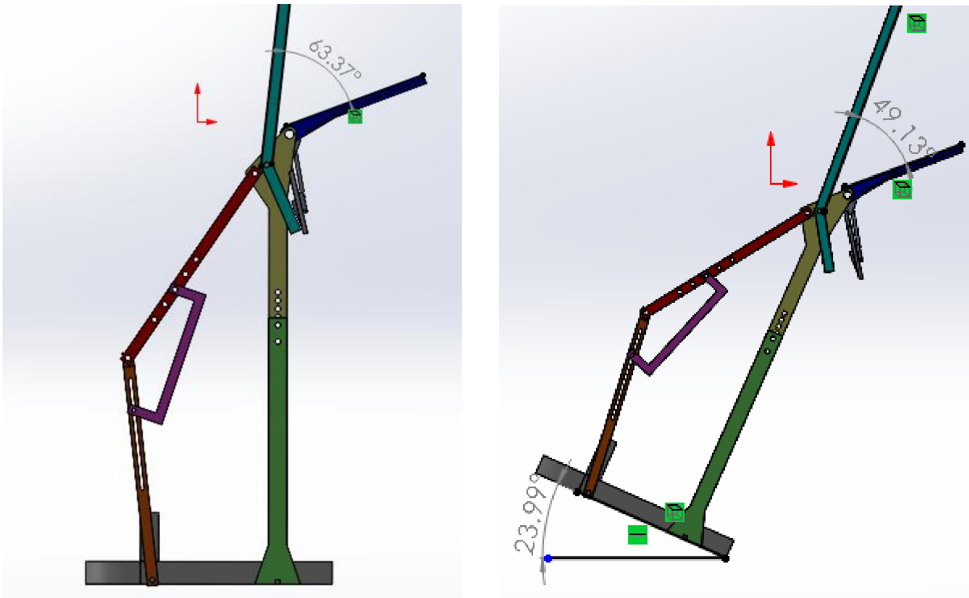

Fig 4(a) Initial Position of Mechanism (b) Final Position of Mechanism

The input angle is 14.2 degrees in the CW direction, The output angle is 24 degrees in the CW direction.

Methods	Input Theta	Output Theta
Analytical Method: MATLAB	14	26.6
Analytical Method: SolidWorks	14.2	24

Forward Kinematic Analysis of both methods almost converges. Since the link lengths were approximated in MATLAB, there is a slight deviation in output values.

4. CONCLUSION:

The exoskeleton is an important societal device that assists personnel with lower limb weakness, knee-injured sports persons, and elderly people for their movement. This project deals with the ease of climbing stairs with minimal use of human energy. This project was aimed to develop a human-operated mechanical actuation device to amplify an input force using a combination of a torsion spring and lever. A novel passive exoskeleton device was successfully developed to assist with stair climbing activity that significantly reduces the stress on knees.

5. LINKS AND REFERENCES

[1] H. Kawamoto, Y. Sankai, “Power assist method based on phase sequence and muscle force condition for HAL”, Advanced Robotics, 2005, 19.7: 717-734

[2] Sado, F., Yap, H. J., Ghazilla, R. A. R., & Ahmad, N. (2019). Design and control of a wearable lower-body exoskeleton for squatting and walking assistance in manual handling works. Mechatronics, 63, (2019), 102272

[3] Zlatko Lovrenovic, Marc Doumit, “Development and testing of a passive Walking Assist Exoskeleton”, Biocybernetics and Biomedical Engineering, Volume 39, Issue 4, 2019, Pages 992-1004

[4] Libo Zhou, Weihai Chen, Wenjie Chen, Shaoping Bai, Jianbin Zhang, Jianhua Wang, “Design of a passive lower limb exoskeleton for walking assistance with gravity compensation”, Mechanism and Machine Theory, Volume 150, 2020, 103840

[5] Four-Bar mechanism- GitHub link for MATLAB Code

[6] Video of recorded mechanism animation in SolidWorks and CatiaV5