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Title: Mechanical Design and Validation of an Auxiliary Active Device for Rehabilitation of the Knee and Quadriceps

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Introduction

- The injuries in the quadriceps or knee adversely affect the biomechanical, this reduces people's quality of life

- For the year 2020, About 3 million persons have difficulties for walking or moving.

- The success in the treatment and the early return to activity depends largely on the rehabilitation process

National Population and Housing Census] [internet]. México: National Institute for Statistics Geography and Information; 2020. Retrieved on March 2022 from: https://www.inegi.org.mx/temas/discapacidad/ (date of access: 1-09-2022).

Physiologic Rehabilitation Device

Active

Pasive

Kinetec Spectra
(Damo, 2012)

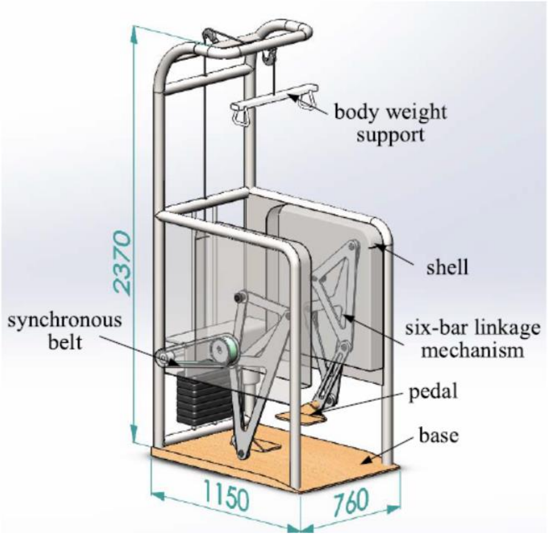
K.I.M
(Phoenix, 2022)

Chaparro Cárdenas, S.L., Lozano Guzmán, A.A., Ramirez Bautista, J.A., Hernández Zavala, A. (2018). A review in gait rehabilitation devices and applied control techniques. Disability and Rehabilitation: Assistive Technology. 13(8), 819-834. |

Current Knee Rehabilitation Devices

SCPM
(Umchid, 2016)

AKROD
(Weinberg, 2007)



Six-bar Mechanism
(Li, 2021)

Methodology

Mechanical Fundamentals for the Knee Rehabilitator:

- Grashof conditions (Watt six-bar linkage)
- Kinematic and dynamic studies
- Finite Element Analysis

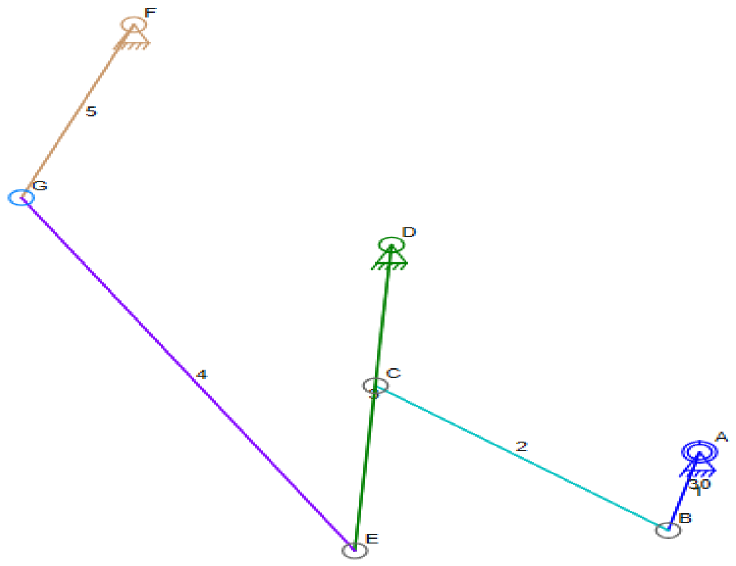
SolidWorks model of the original extension machine where is possible to see that it depends on the person to generate the movement.

Mechanical Design of the Knee Rehabilitation Machine

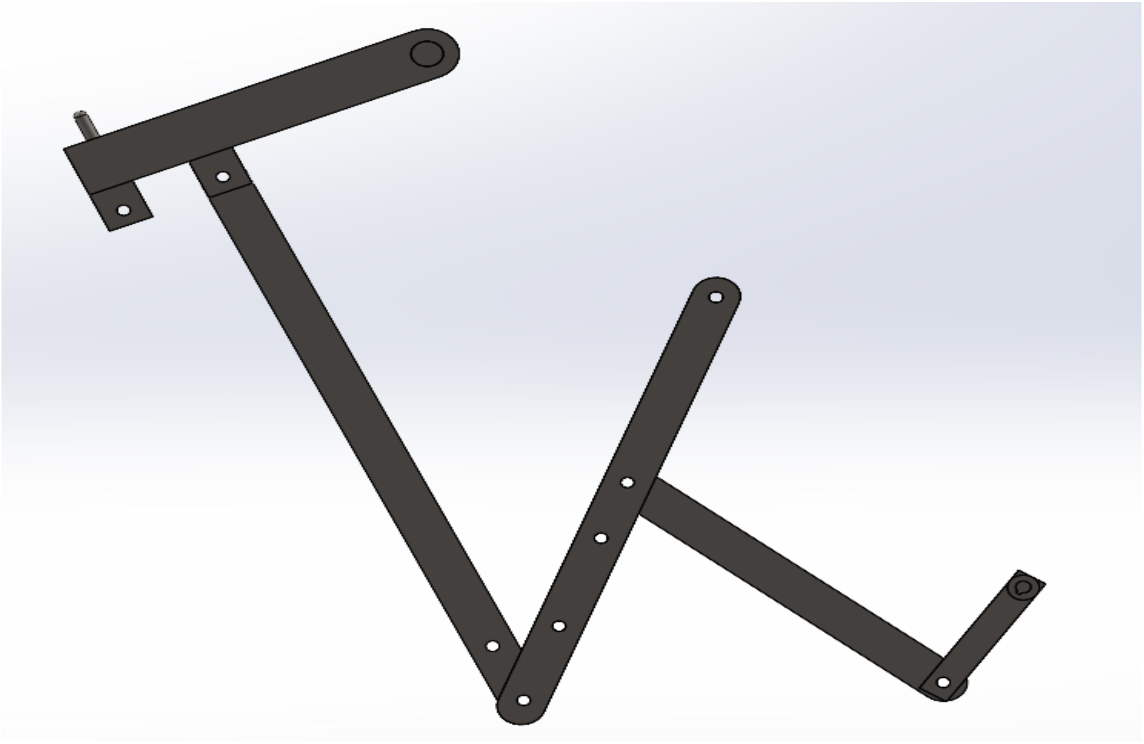
Condition	Specifications
Frame	Structure of a leg extension machine made on steel RHS 2”x2” gauge 10
Motor DC	Maxon EC-i 40, 18 V, 5.46 A, with geared motor Maxon GP 42C, maximum discontinuous torque 22.5 Nm
Speed	30 RPM
ROM	from 20° to 120°
Links	Designed in A36 steel
Supports	Steel RHS on A36 steel 2”x2” gauge 14
Transmission	Gears on Nylamid, width face of 1”, Diametral pitch 10

Specifications of the system.

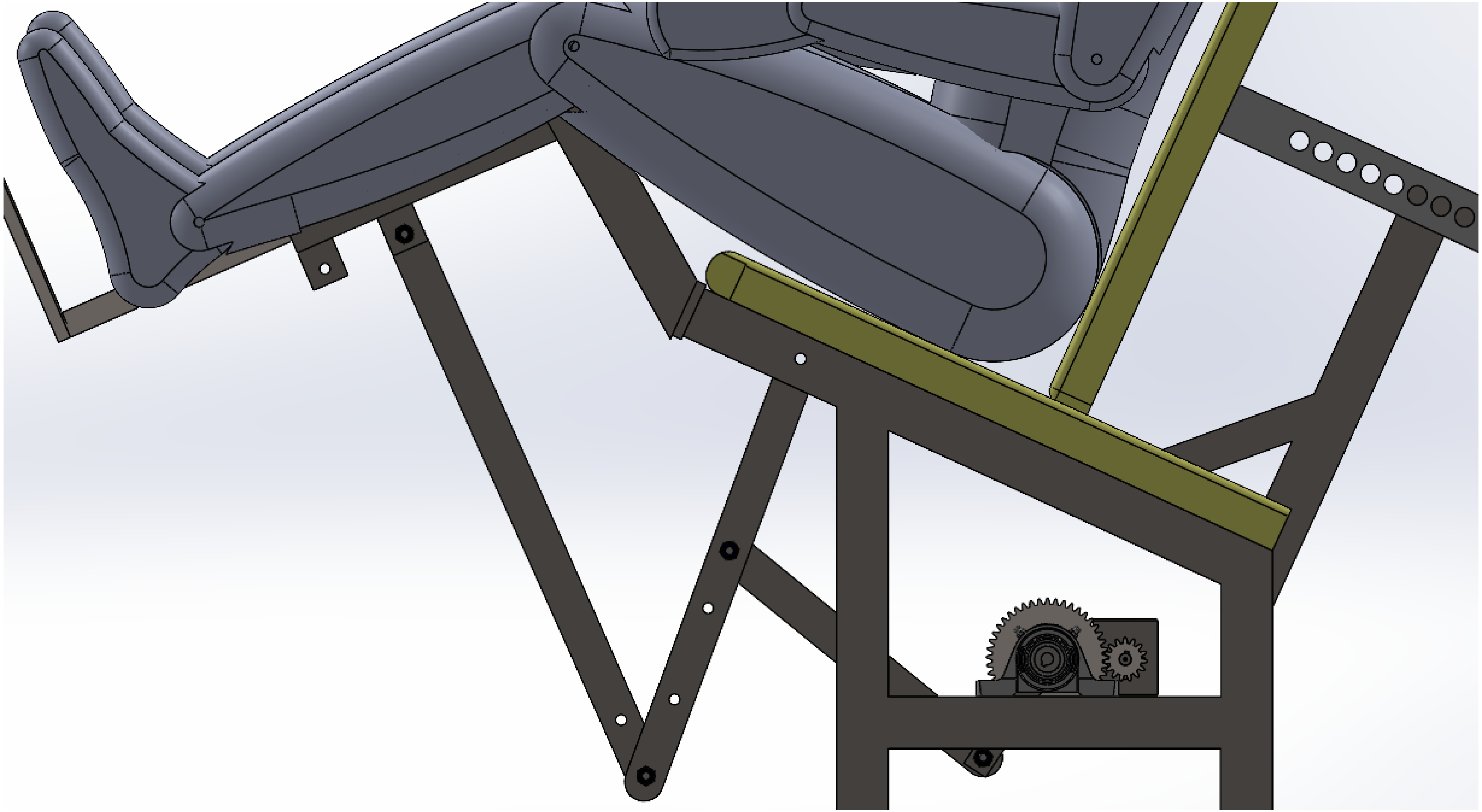
Proposed Mechanism



The solid works scheme presents fixed points F, D, and A; the mobile links are B, C, E, and G. The link A is where the motor should be placed to start the movement.

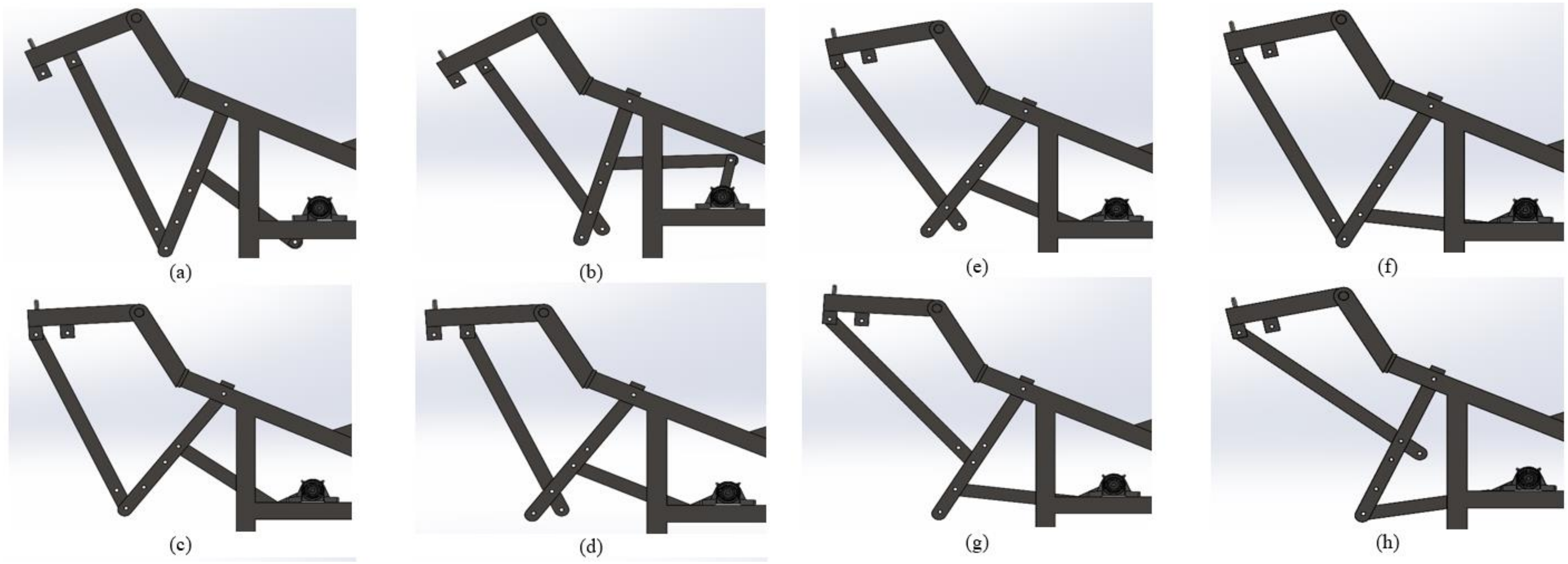


SolidWorks design for the six-bar Watt linkage mechanism is presented. It is important to notice that the smallest link at the right corresponds to the motor connection. The link on the left generates the leg movement. The holes in the middle links allow reconfiguring to have a smaller range of motion.



The assembly is presented with the six-bar Watt linkage placed into the machine. Notice that a rowlock is the support for the transmission gear, while the motor is fixed with an iron base.

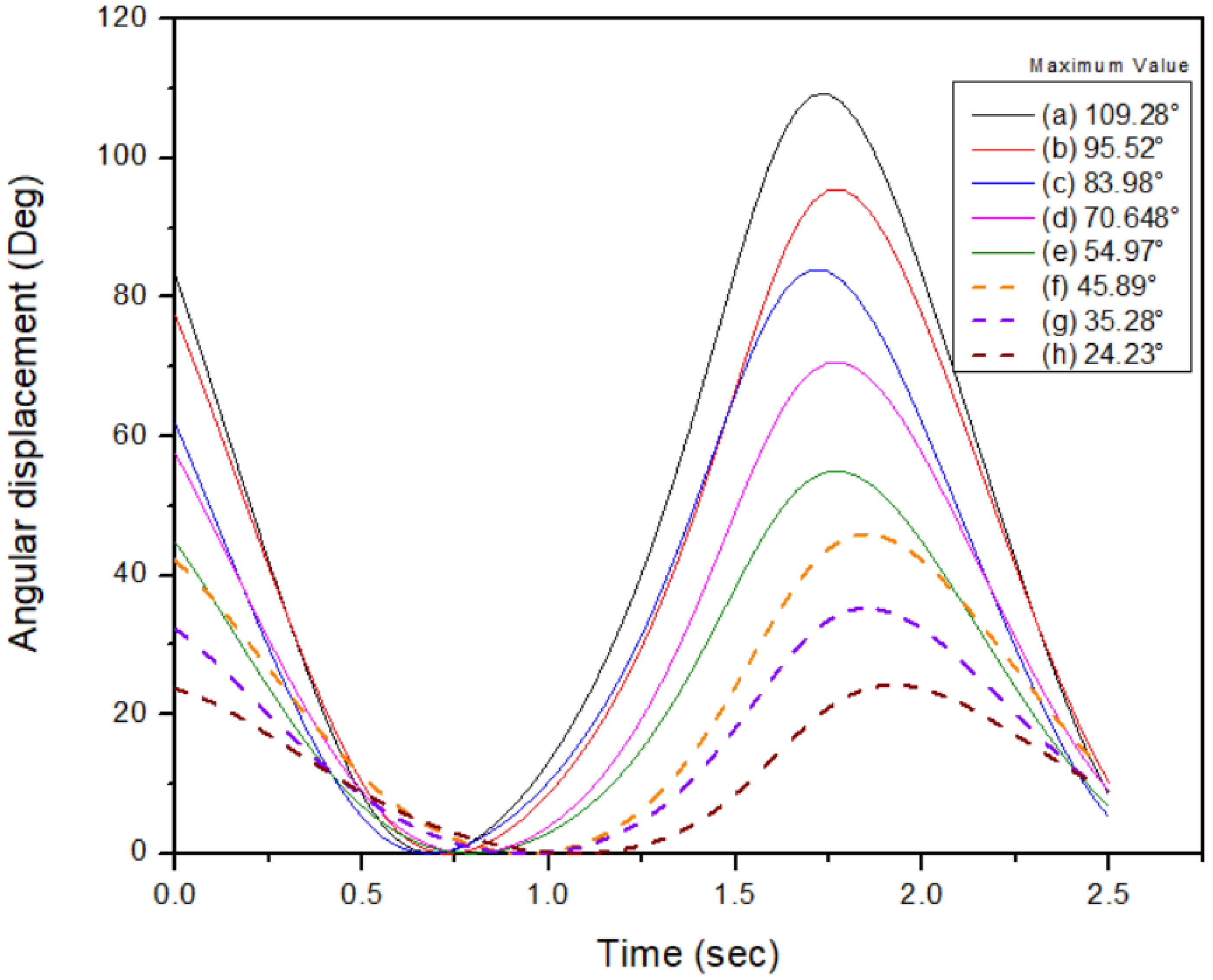
Possible combinations



The different mechanical configurations that can be used to modify the range of motion (***a*** to ***h***). Being ***a*** the widest with a ROM of 109.28°, and the shortest path is given by ***h*** with 24.23°.

Results

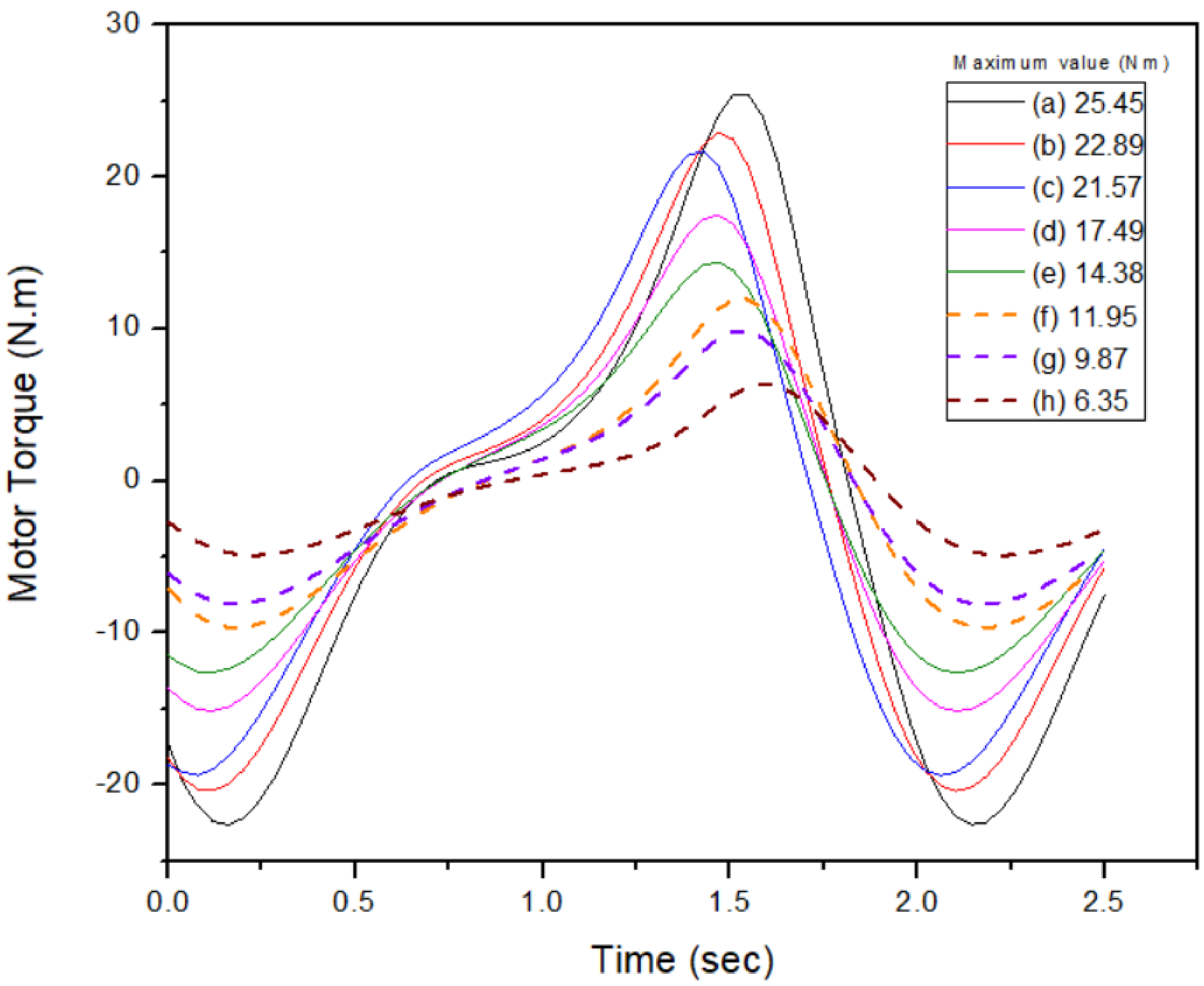
Range of motion (ROM)



Plot of motion for the different configurations tested (***a*** to ***h***). It is noticeable that the wider path is realized by ***a*** rather than by ***h***. Intermediate configurations are useful for midway rehabilitation movements.

Torque

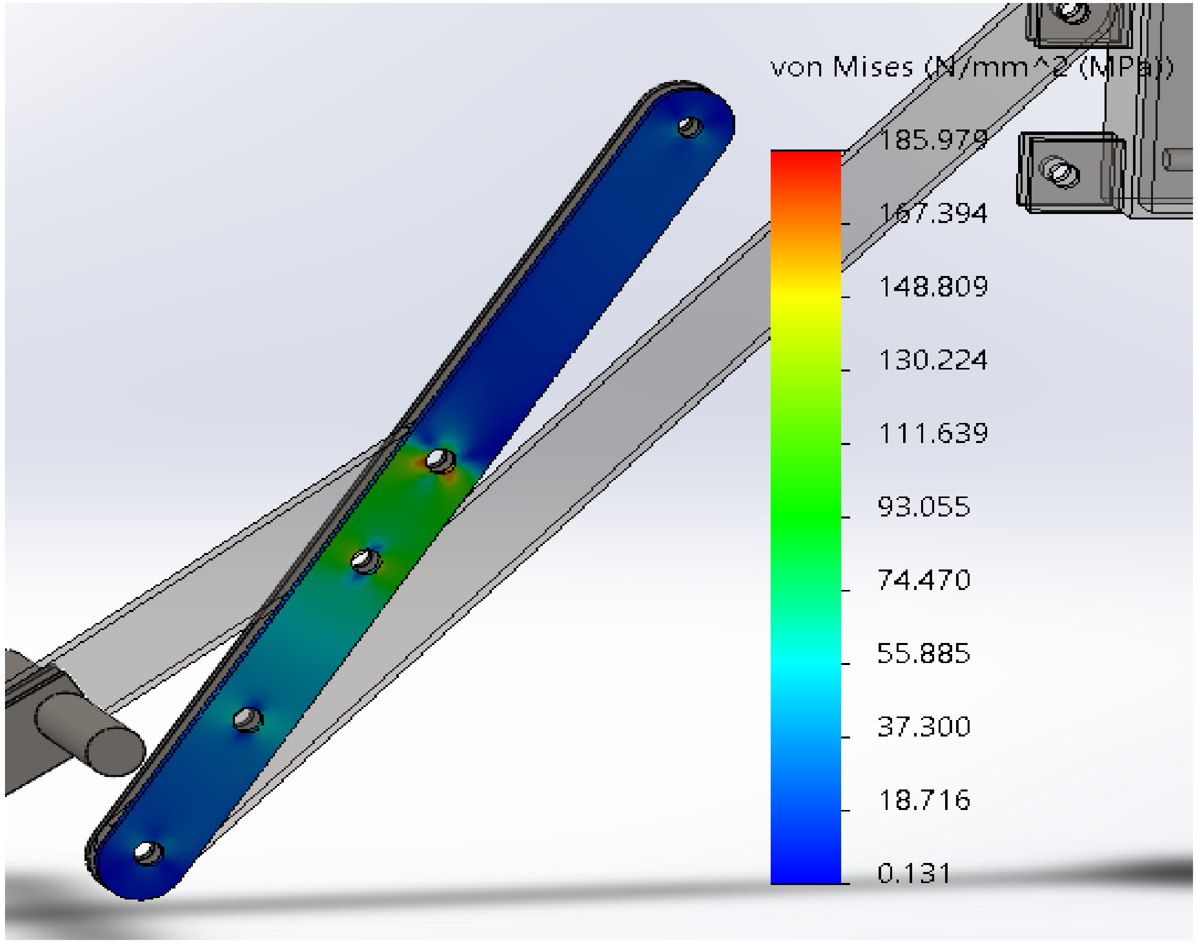
(Load of 7 Kgf that simulates the weight of the legs)



Plot of torque for the different configurations tested (***a*** to ***h***). It is noticeable that while ***a*** realizes the wider path it requires more torque. The case of ***a*** requires 25.45Nm, while the ***h*** case requires 6.35 Nm.

Finite Element Analysis

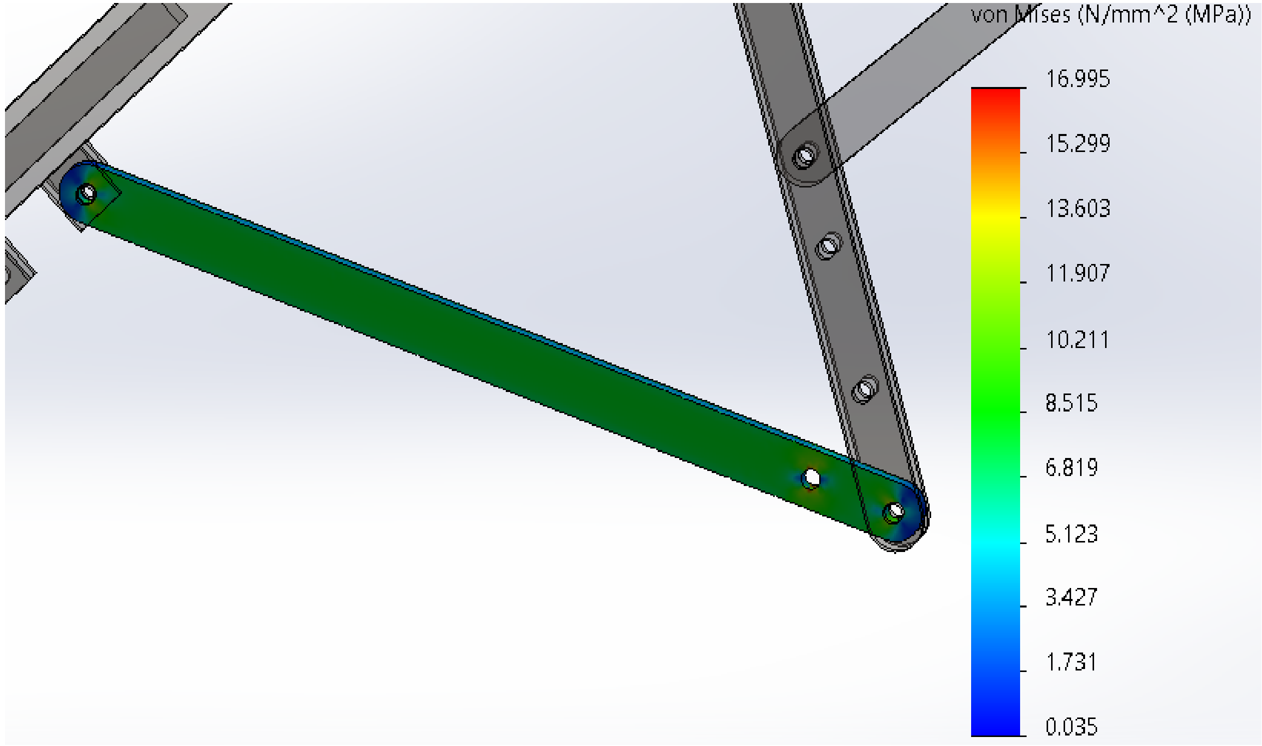
Weakest link
(186 MPa)



Stresses and safety factor for the elements of the mechanism.

Strongest link

(17 MPa)



Stresses and safety factor for the elements of the mechanism.

Conclusions

- The results shown in this study prove that the proposed machine met the task of providing a wide variety of ranges of motion that cover from the early to last stages of physical rehabilitation.

- It was also observed that reductions in weight, material changes, and topology optimizations, could be done, and consequently, the reduction of the necessary torque

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