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Advanced Passive Motion Machine (APMM) for Rehabilitation of Patients with Lower Limb Ailments-An Physio-mechanical Approach

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Abstract: ***Lower limb impairments due to injuries, surgeries, or neurological disorders often require long-term physiotherapy. Continuous Passive Motion (CPM) devices have traditionally been used to facilitate early joint mobility. This paper presents an Advanced Passive Motion Machine (APMM) for rehabilitation of patients with lower limb ailments. The design integrates programmable motion control, safety feedback mechanisms, and adaptable limb support. APMM focuses on modularity, real-time feedback, and cost-effective manufacturing. Simulation and initial clinical trials show promising results in improving rehabilitation outcomes.***
Keywords: Passive motion, rehabilitation, lower limb, motorized therapy, biomechanics, APMM.

Abstract: ***In recent years, there has been remarkable progress in the field of medical technology, particularly in the domain of rehabilitation. Among the many innovative solutions that have emerged, continuous passive machines (CPMs) have gained significant attention and appreciation for their effectiveness in aiding the recovery process for various musculoskeletal injuries and conditions. This approach delves into the fascinating world of CPMs specifically designed for ankle, knee, and hip rehabilitation, highlighting their benefits, functionality, and potential applications. Continuous passive machines are mechanical devices used to facilitate passive movement of joints. These machines play a pivotal role in rehabilitating individuals who have suffered from a range of orthopedic injuries, including ankle sprains, knee ligament tears, hip replacements, and other musculoskeletal conditions. By employing a continuous, controlled range of motion, CPMs promote joint mobility, reduce stiffness, enhance circulation, and facilitate the healing process. For patients recovering from ankle, knee, or hip injuries, APMM offer several advantages over traditional rehabilitation methods. Firstly, these machines allow for precise control and customization of the range of motion, speed, and intensity of movement. This adaptability ensures that the treatment aligns with the specific needs and limitations of each patient, promoting safety and comfort during rehabilitation.***
Keywords: Passive motion, rehabilitation, lower limb, motorized therapy, biomechanics, APMM.

I. INTRODUCTION

Continuous passive motion (CPM) therapy and the possibility of its use after total knee replacement (TKR) and hip surgery to assist in achieving range of movement (ROM) is widely known in orthopedics and physiotherapy. continuous passive motion is practiced in hospitals for the patients unable to gain sufficient range of motion by machine or manually assisted. CPM is only one method available to physiotherapists to help in achieving the desired ROM at the joint. The therapy may also be given manual passive or active passive way but it must be applied by a machine, because manual passive motion is inconsistent, causes more pain and does not last long enough.

The most common are injuries that affect the hip joint, knee joint and Ankle joint. Hip, Ankle and knee are most essential joints for walking, running, and climbing stairs. A continuous passive motion machine (CPM) is available for knee therapy to begin motion as soon as possible following surgery, but it has limitation, it cannot treat a patient of hip Abduction, Adduction, Internal and External rotation of hips. The objectives of this research is to bring interest in research on passive motion machine for rehabilitation after hip surgery thereby working on hip therapies using machines.

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1) Existing Machines

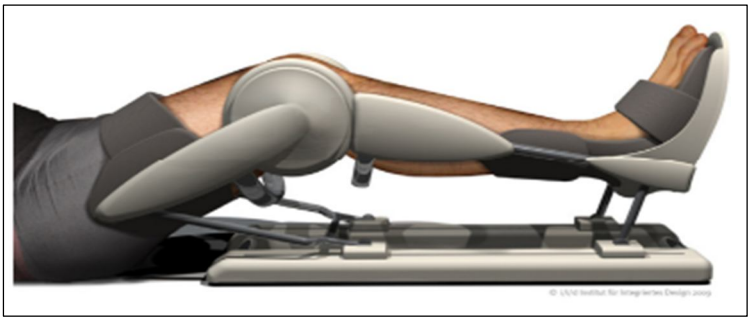


Fig. 1: Knee Therapy



Fig. 2: Ankle Therapy



Fig. 3: Hip Therapy

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II. AIM & OBJECTIVES

1) To study and apply ergonomics in the system design.
2) In-depth study of synthesis of mechanism of APMM
3) To decide research methodology for development of APMM.
4) To develop a machine which can treat a patient of hip, knee and ankle problem.
5) To develop cost efficient light weight less area utilizing APMM.
6) To study different sensors and synchronous motor to be used in designing APMM.
7) To increase patient's range of motion of hip, knee and ankle.

III. ORIGIN OF THE RESEARCH PROBLEM

The prevalence of lower limb ailments, such as fractures, ligament injuries, and postoperative recovery from surgeries like knee or hip replacements, is significant and continues to rise globally. According to recent statistics, over 15 million people worldwide undergo knee or hip replacement surgeries annually, with a substantial portion requiring extensive rehabilitation. These conditions significantly impair patients' mobility, independence, and overall quality of life, posing a considerable burden on healthcare systems.

Current rehabilitation methods, including physical therapy and traditional passive motion machines, present several challenges. These techniques often lack efficiency, and does not support bed ridden patients, leading to inconsistent patient outcomes. There is a pressing need for advanced rehabilitation solutions that can overcome these limitations.

The concept of an Advanced Passive Motion Machine (APMM) aims to revolutionize lower limb rehabilitation by offering precise motion control, adaptability to individual patient needs, enhanced comfort, and improved monitoring of progress. The development and analysis of APMM address critical research gaps, including the need for bed ridden patients, overcoming fixed flexion deformation issue and reducing patient's mobility.

Interdisciplinary: - Relevance: Medical Science (Rehabilitation of Patients with lower limbs ailment)

IV. PROBLEM FORMULATION

Advanced Passive Motion Machine (APMM) will be designed on a bed-cum-chair. Single machine will be designed and Hip, Knee and Ankle therapies will be performed on same machine. The machine will be initially in straight position to avoid Fixed flexion deformity (FFD) of knee joint with 0°-45° range of motion.

For Ankle therapy existing mechanism will be adapted to perform therapies like Planter-flexion, Dorsiflexion, inversion and Eversion.For Hip therapy two mechanisms has to be designed. First for flexion 45° maximum raise and second for Abduction and Adduction for 0°-35° range of motion [2].So, Advanced Passive Motion Machine (APMM) would let Rehabilitation of patient of fracture, ligaments injury or even bed ridden treated in lying position

V. DESIGN PARAMETERS OF BED

Size, dimensions and controls of resting sections (bed-cum-chair) are as mentioned:

Controls: The bed has to meet the following demands: - The speed of actuators when performing functions must be constant. - The functions will be chosen and controlled by pressing function keys.

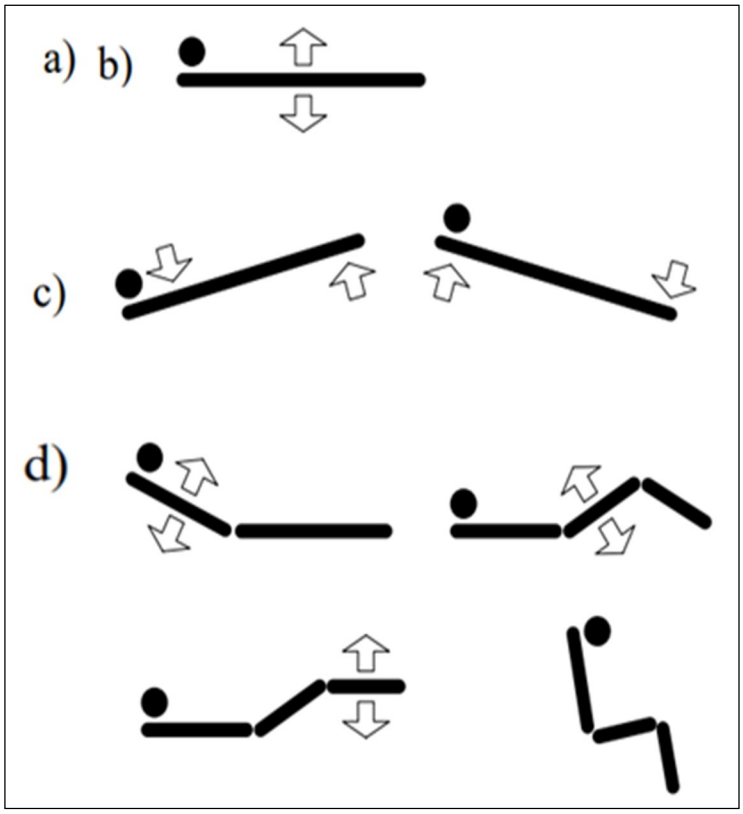
The resting sections (bed-cum-chair) has to meet the following demands: - The size is standard. Height: 450 mm, width: 400 mm, length: 2000 mm. - Weight capacity: 500 kg.

The idea is that the resting sections (bed-cum-chair) includes many frames, each frame is coupled with a mechanism which performs one or some functions:

1) Height adjustment
2) Lying position
3) Trendelenburg/Reverse Trendelenburg position
4) Sitting in various positions.

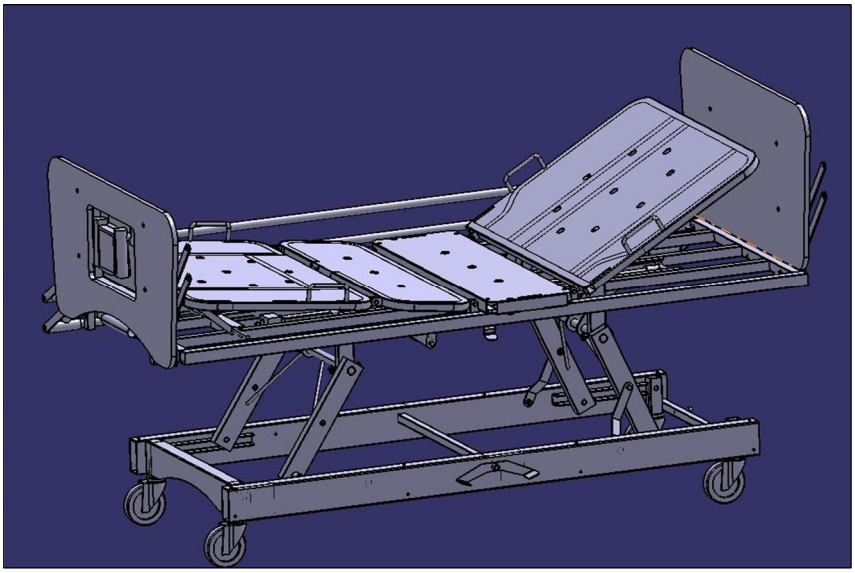
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VI. CAD MODEL OF BED

The CAD Model has been prepared as per standards. Height: 450 mm, width: 400 mm, length: 2000 mm. - Weight capacity: 500 kg

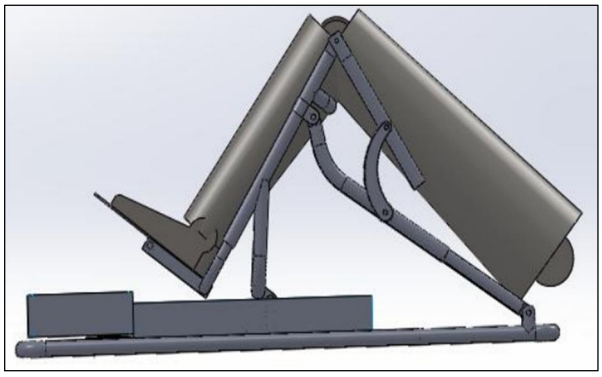




VII. DESIGN PARAMETERS

For Hip and Knee therapy two mechanisms will be designed. First for flexion 45° maximum raise and second for Abduction and Adduction for 0°-35° range of motion [2].Hip and knee joints each possess one degree of freedom, while ankle joint has three degree of freedom. Joints are linked with elements that represent hip and shin bones. The length of those can be freely adjusted, which results from different bone lengths of various patients. The part representing a hip bone will be made regulated from 30 to 60cm.The part representing an ankle joint, measuring 30cm.

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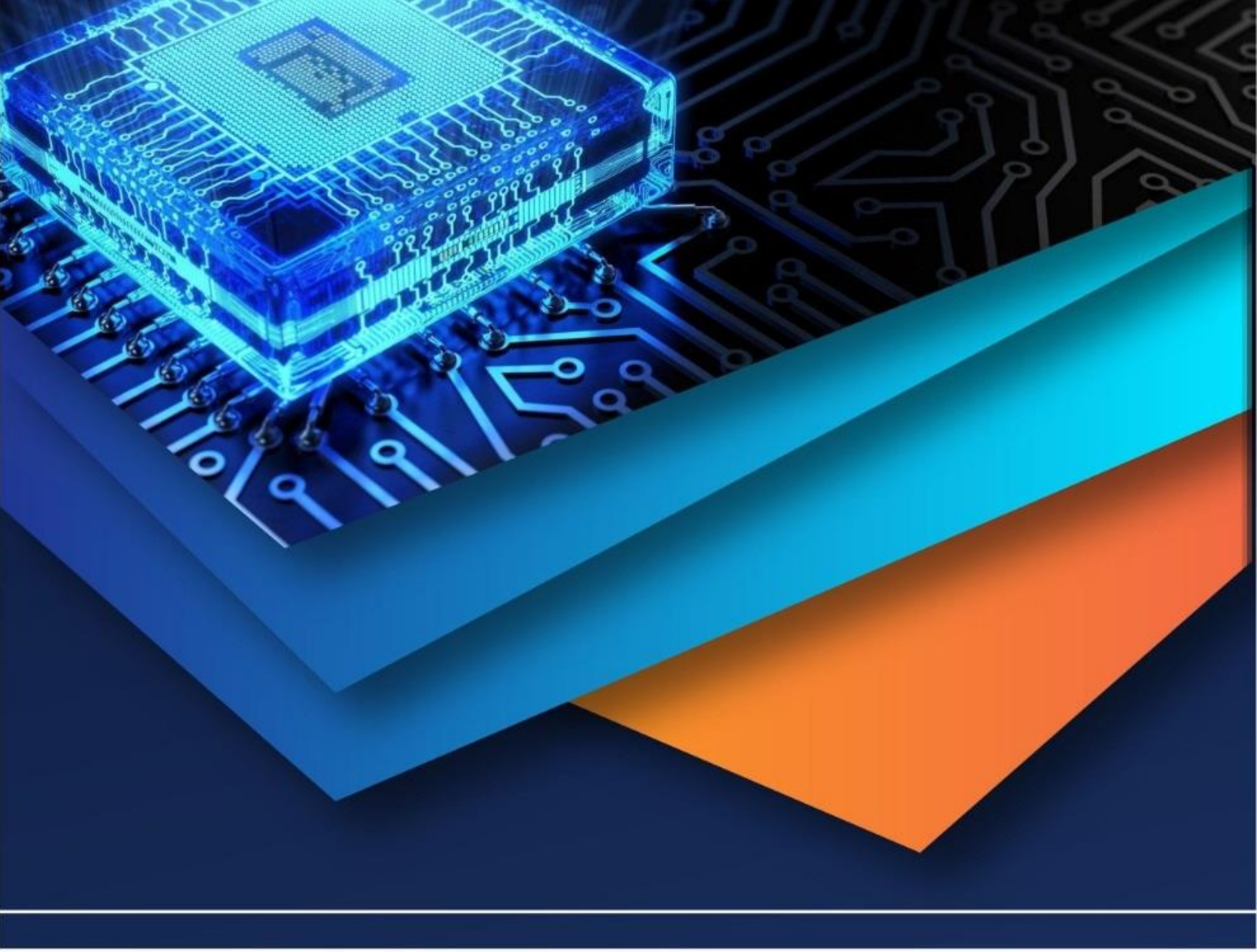
VIII. CONCLUSION

The Advanced Passive Motion Machine (APMM) represents a viable, adaptable solution for lower limb rehabilitation. Its modular design and real-time monitoring enable safer and more efficient therapy. Future work includes integrating wireless data transmission and AI-based motion adaptation.

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