iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** VI **Month of publication:** June 2024

DOI: https://doi.org/10.22214/ijraset.2024.63053

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VI June 2024- Available at www.ijraset.com

Analysis of Ergonomic Designed Healthcare Bed for Lateral Tilting and Rotation

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Abstract*: *This project revolves around the analysis of a novel healthcare bed designed to address the needs of patients with limited mobility, offering lateral tilting and rotation capabilities, which is crucial for their comfort, recovery, and healthcare providers' efficiency. The primary aim of this project is to create a healthcare bed that improves patient mobility through lateral tilting and rotation mechanisms. By utilizing engineering solutions, we intend to design a healthcare bed that reduce the physical strain on healthcare providers during patient handling. The project begins with a comprehensive literature review of existing hospital bed designs and relevant medical guidelines. It progresses to the conceptualization of the bed, considering the specific requirements of patients and healthcare professionals. Healthcare bed, with detailed technical specifications is made using solidworks premium 2019 SP5.0 software which is later analysed using ansys 2020 R1 software
Keywords: Design novel healthcare bed, offering lateral tilting and rotation, analysed using ansys 2020 R1 software

I. INTRODUCTION

T A healthcare bed, also known as a hospital bed, is a specialized bed designed for use in healthcare settings to provide comfort, support, and medical care for patients. These beds are equipped with various features to accommodate the unique needs of individuals receiving medical treatment, recovering from illness or surgery, or dealing with chronic conditions. Healthcare beds play a crucial role in patient care and contribute to the overall wellbeing and comfort of individuals receiving medical treatment in hospitals, clinics, and other healthcare facilities. Their design and features are tailored to address the specific needs of patients and healthcare providers.

A. Challenges And Benefits

Advanced healthcare beds with sophisticated features can be expensive, posing financial challenges for healthcare facilities, especially in resource-constrained settings. Regular maintenance and occasional repairs are necessary for healthcare beds to ensure optimal functionality. This can be time-consuming and may lead to temporary bed unavailability. Healthcare facilities often face space constraints, and accommodating specialized beds for various patient needs can be challenging. Healthcare professionals need proper training to operate and utilize the features of advanced healthcare beds effectively. Lack of training may lead to underutilization or misuse. 2 Maintaining cleanliness and infection control in and around healthcare beds is critical. The design complexity of certain beds can make thorough cleaning more challenging. Despite advancements, achieving the optimal balance between clinical functionality and patient comfort can be challenging. Patient comfort is crucial for recovery and well-being. Integrating healthcare beds with electronic health records (EHR) or other healthcare systems for seamless data flow can be a technical challenge that healthcare facilities may face.

B. Benefits

Healthcare beds enhance patient care by providing adjustable positions that cater to individual needs, contributing to comfort and well-being. Specialized mattresses and pressure-relieving features in healthcare beds help prevent pressure ulcers, a common concern for patients with limited mobility. Features like height adjustment and mobility assistance contribute to better patient mobility, facilitating activities like transfers and rehabilitation exercises. Side rails and adjustable bed heights contribute to patient safety, reducing the risk of falls and injuries. Healthcare beds come with various features that can be customized to meet specific patient requirements, ensuring personalized care. Some healthcare beds integrate with monitoring devices, providing healthcare professionals with real-time data for better patient management. Electric controls, remote capabilities, and CPR release functions enhance the efficiency of healthcare professionals in providing timely and effective care.

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Healthcare beds cater to a wide range of medical needs, including bariatric care, maternity care, and specialized patient populations, contributing to versatile patient care. 3 Features like height adjustment reduce strain on caregivers, promoting a more comfortable and ergonomic caregiving environment.

C. Objective

The primary objective of this project is to conduct a comprehensive analysis of an ergonomically designed healthcare bed with lateral tilting and rotation capabilities. The focus will be on evaluating the bed's design, functionality, and impact on patient care and healthcare professional tasks.

D. Different Functions In Healthcare Bed

Adjustable Height: Allows the healthcare bed to be raised or lowered to a comfortable working height for healthcare professionals. It aids in patient transfer and caregiver access. Head and Foot Adjustment: Enables the adjustment of the head and foot sections of the bed independently. This feature is useful for patients who need to be in a semi¬ upright position or have their legs elevated. Trendelenburg and Reverse Trendelenburg Positions: Allows the bed to be inclined with the head lower than the feet (Trendelenburg) or vice versa (Reverse Trendelenburg). These positions are often used in surgical procedures or to address specific medical conditions. Side Rails: Provides safety by preventing patients from accidentally rolling out of bed. Side rails can be raised or lowered as needed. Mobility Wheels: Equips the bed with wheels for easy movement within healthcare facilities. Locking mechanisms ensure stability when needed. Pressure-Relieving Mattresses: Specialized mattresses designed to reduce pressure on specific areas of the body, helping to prevent pressure ulcers. 4 Remote Controls: Electrically adjustable beds often come with remote controls, allowing patients to adjust the bed's position without assistance. Weight Capacity Adjustment: Some healthcare beds, especially bariatric beds, allow adjustment of weight capacity to accommodate patients of different sizes. Integrated Scales: Measures and displays the patient's weight directly on the bed, eliminating the need for separate weighing scales. Cardiac Chair Position: Raises the head section and elevates the knees, creating a position similar to sitting in a recliner. This can be beneficial for patients recovering from cardiac surgery. Heating and Cooling Features: Some advanced healthcare beds come with integrated heating or cooling elements to enhance patient comfort. Entertainment and Connectivity: Includes features such as USB ports, power outlets, and integrated entertainment systems to enhance the patient's experience during extended stays.

E. Lateral Tilting And Rotation Capabilities In Healthcare Bed

Lateral tilting and rotation capabilities in healthcare beds are advanced features designed to enhance patient care and improve the working conditions for healthcare professionals. These capabilities provide additional flexibility in patient positioning, contributing to comfort, mobility, and various medical procedures..

II. PROBLEM IDENTIFICATION

Design Problems

Most of the typical healthcare bed only consist of horizontal movement which is used to rise the head leg of the patient so that patient’s vertical movement is done by the healthcare professions

III. DESIGN OF HEALTHCARE BED

A. Healthcare Bed

Healthcare bed design is a specialized field of product design focused on creating beds that cater to the unique needs of patients in healthcare settings, such as hospitals, clinics, long-term care facilities, and home care.

B. Design Process

Designing a healthcare bed involves a systematic and multidisciplinary design process to ensure that the bed meets the unique needs of patients and healthcare professionals. Project Definition and Research: Define the project goals, including the specific needs and requirements of the target users. Conduct extensive research to understand the challenges and opportunities in healthcare bed design. Consider input from healthcare professionals and patients. Concept Generation: Brainstorm and develop multiple conceptual designs. Consider factors such as adjustability, comfort, safety, and ease of use. Generate innovative ideas to address the identified needs. Preliminary Design: Select the most promising concepts and create preliminary designs.

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These designs should include rough sketches, 2D drawings, or 3D models to visualize the bed's form and features. Detailed Design and Engineering: Refine the selected preliminary design based on engineering principles. Ensure that the bed meets safety standards, load-bearing requirements, and durability criteria. Develop detailed CAD (Computer-Aided Design) drawings and specifications. Ergonomic Evaluation: Perform ergonomic evaluations to assess how well the bed design aligns with ergonomic principles. This involves evaluating comfort, ease of use, and alignment with the human body's natural posture. Iterative Redesign: Based on user feedback and testing results, iterate on the design to address any identified issues or enhance the bed's features. This may involve several redesign cycles. 19 Materials and Manufacturing Selection: Finalize the choice of materials, production methods, and manufacturing partners for the bed. Consider factors such as material durability, ease of cleaning, and sustainability. Safety and Regulatory Compliance: Ensure that the bed design complies with safety and regulatory standards relevant to healthcare equipment, such as those set by healthcare authorities and standards organizations. The design process for a healthcare bed should prioritize patient comfort, safety, and ease of use while meeting the practical needs of healthcare professionals. Collaboration with healthcare experts and end-users is crucial to ensure that the final product aligns with real-world requirements.

IV. MECHANISM USED WEDGE CAM MECHANISM

A wedge cam mechanism, also known as a wedge cam system, is a type of mechanical linkage that converts rotary motion into linear motion. It consists of a cam and a follower. The unique feature of a wedge cam is its non-circular shape, which results in controlled linear movement of the follower as the cam rotates.

A. Components Design

Design of healthcare bed consist of following components
Bed base
Wedge cam setup
Side block assembly

1) BED BASE

The hospital bed base refers to the foundational structure or framework of a hospital bed. It is the structural support system that holds the mattress and other components of the bed. The design and features of the bed base play a crucial role in patient comfort, safety, and functionality. Here are some key aspects related to hospital bed bases

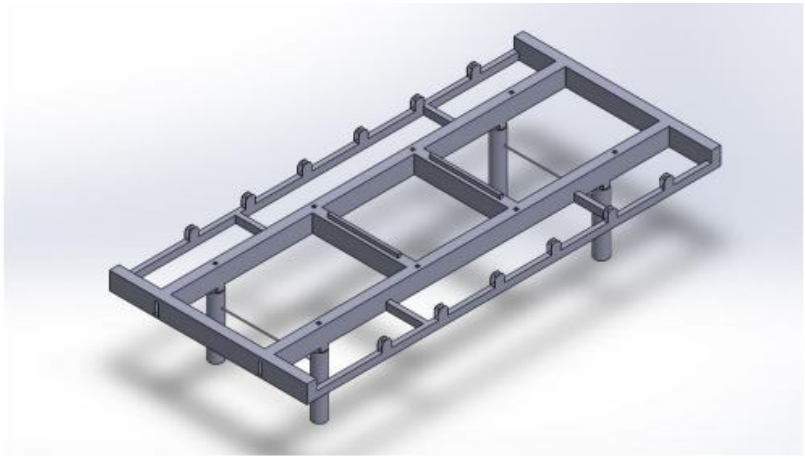


Fig. 1 Design of base of the bed.

Material:

- Hospital bed bases are commonly constructed from durable materials such as steel or aluminum. These materials provide strength and stability to support the weight of the patient and other bed components.
- 201 annealed stainless steel is selected for my design because of its properties Elastic Modulus 207000 N/mm^2 Poisson's Ratio 0.27 N/A Tensile Strength 685 N/mm^2 Yield Strength 292 N/mm^2 Tangent Modulus N/mm^2 Thermal Expansion Coefficient 1.7e-05 /K Mass Density 7859.9999 kg/m^3 Hardening Factor 0.85 N/A



Fig. 2 Design of base of the bed with all necessary features

2) WEDGE CAM SETUP

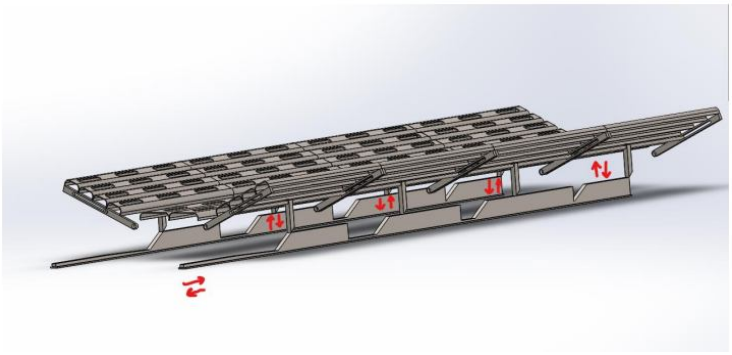


Fig. 3 Wedge cam setup

A wedge cam setup typically involves the use of a wedge cam mechanism. A wedge cam is a type of mechanical linkage that converts rotational motion into reciprocating (back-and-forth) linear motion. This mechanism is often used in various engineering applications, including machinery, automation systems, and manufacturing processes. Here's a general overview of a wedge cam setup:

Components of a Wedge Cam Setup:

- *Cam:* The cam is a rotating component with an irregular shape (usually oblong or egg-shaped). As the cam rotates, it imparts motion to the follower.

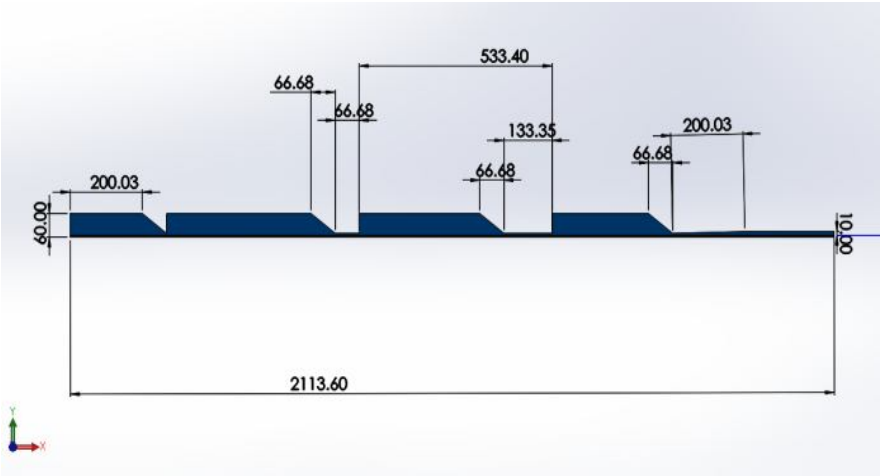


Fig. 4 Wedge CAM dimension

- *Follower:* The follower is a component that makes contact with the cam. It follows the shape of the cam, translating the rotational motion of the cam into linear motion.

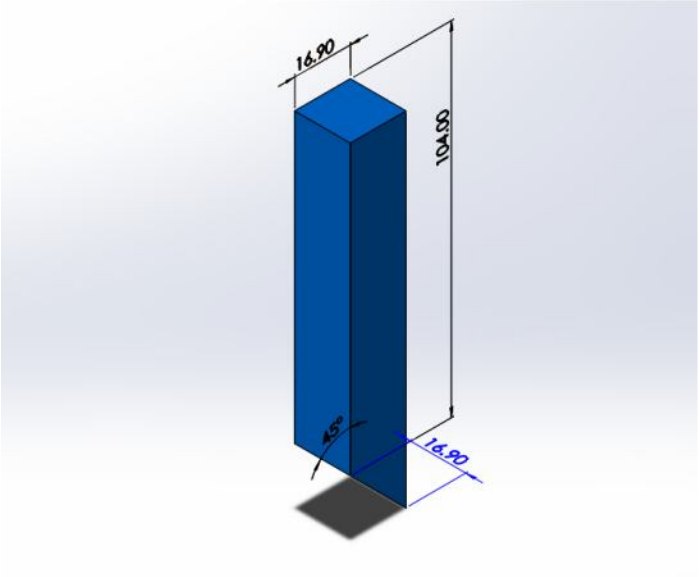


Fig. 5 Follower dimension

- *Base or Frame:* The base or frame provides support for the cam and follower assembly. It is essential for maintaining stability and alignment. • In my design frame of the wedge cam setup is integrated to the base of the bed

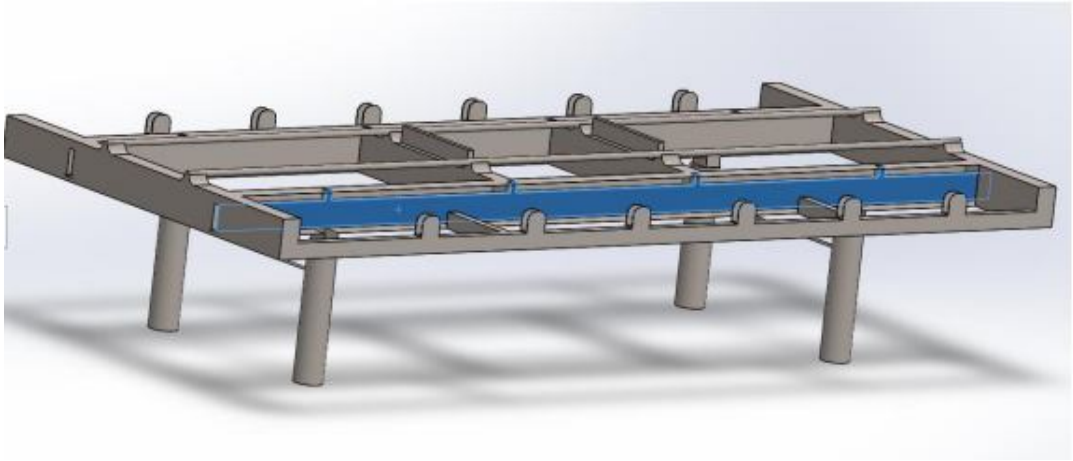


Fig. 6 Wedge frame integrated with bed base

- *Linkage or Connecting Rod:*

A linkage or connecting rod connects the follower to the desired output or another part of the machinery. It ensures that the linear motion generated by the follower is transmitted to the intended location.

Working Principle:

- *Cam Rotation:* The wedge cam is mounted on a rotating shaft. As the shaft rotates, the cam follows a circular path.
- *Follower Movement:* The follower, in contact with the cam, experiences varying levels of displacement as the cam rotates. The irregular shape of the cam determines the specific motion profile (linear, oscillating, etc.) of the follower.
- *Linear Output:* The linear motion of the follower is harnessed for a particular purpose. This could involve moving a tool, actuating a mechanism, or performing a specific function in a machine.

3) Side Block Assembly

It is a block of individual parts that is connected to the follower of the wedge CAM setup. Its purpose is to rise and dawn of the human anatomy to achieve the lateral tilting and rotation of the patient.

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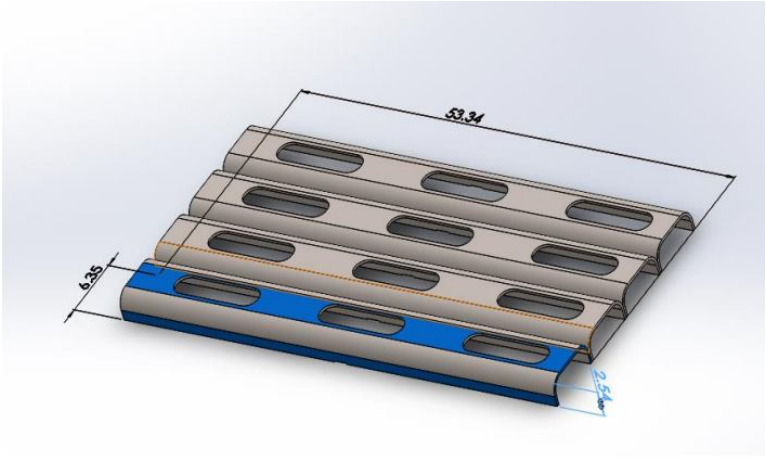


Fig. 7 Individual block

V. DESIGN FOR WEDGE CAM

Solid Works software is used to prepare the healthcare bed general design. The harvester is made up of several little parts of different sizes that are constructed from independent part drawings. In this design wedge is moved back and forth to rise the follower. The follower is connected to the individual block. The length of rise is 204 mm which rise the follower to attain the 45 0 angle of the individual block

Total length of the wedge cam is 2133.6mm Angle of rise is 66.68

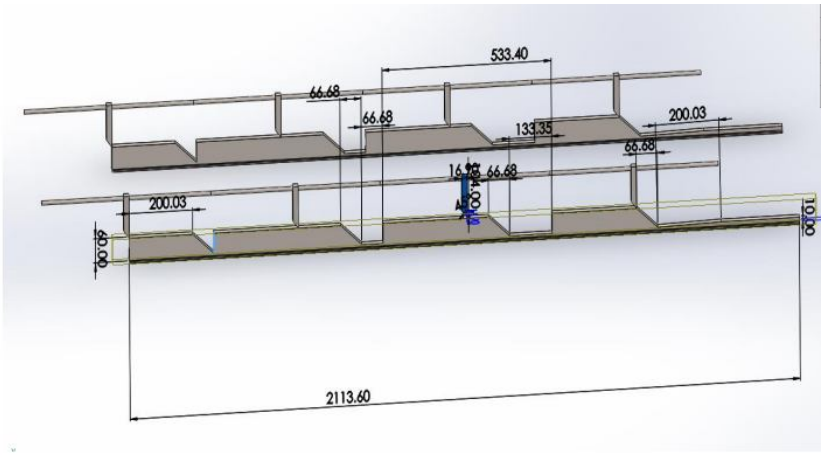


Fig. 8 Wedge cam dimension in assembly

A. Assembly

To achieve the desired device output, the parts created in the Solid Works software are assembled. The device assembly is made up of two sub-assemblies. One is the bed with wedge CAM assembly, and the other is individual block assembly. The two assemblies work together to form healthcare bed

1) Wedge Cam Assembly

A wedge cam assembly is a mechanical system that incorporates a wedge cam mechanism, which converts rotary motion into linear motion using an irregularly shaped cam and a follower. The assembly typically includes several components that work together to produce the desired motion profile. Assembly is done is solidworks. All the components are held in place by the bed base i.e. bed base is fixed. Every part is shifted in relation to the bed base. In wedge cam assembly frame of the wedge cam is integrated with bed base and wedge cam is inserted in the frame Follower is aligned at the top of the wedge cam.

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Follower is mate to the frame of the wedge cam i.e. bed base The specific design and application of a wedge cam assembly can vary widely based on the intended use and engineering requirements. Engineers use these assemblies to convert rotary motion into controlled linear motion

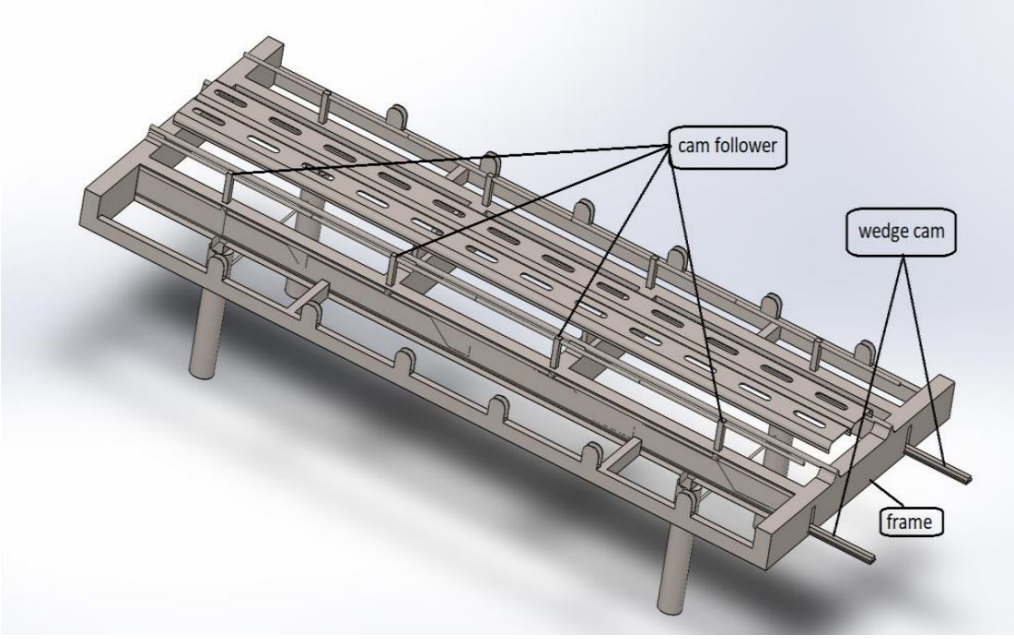


Fig 9 Parts of wedge cam in assembly

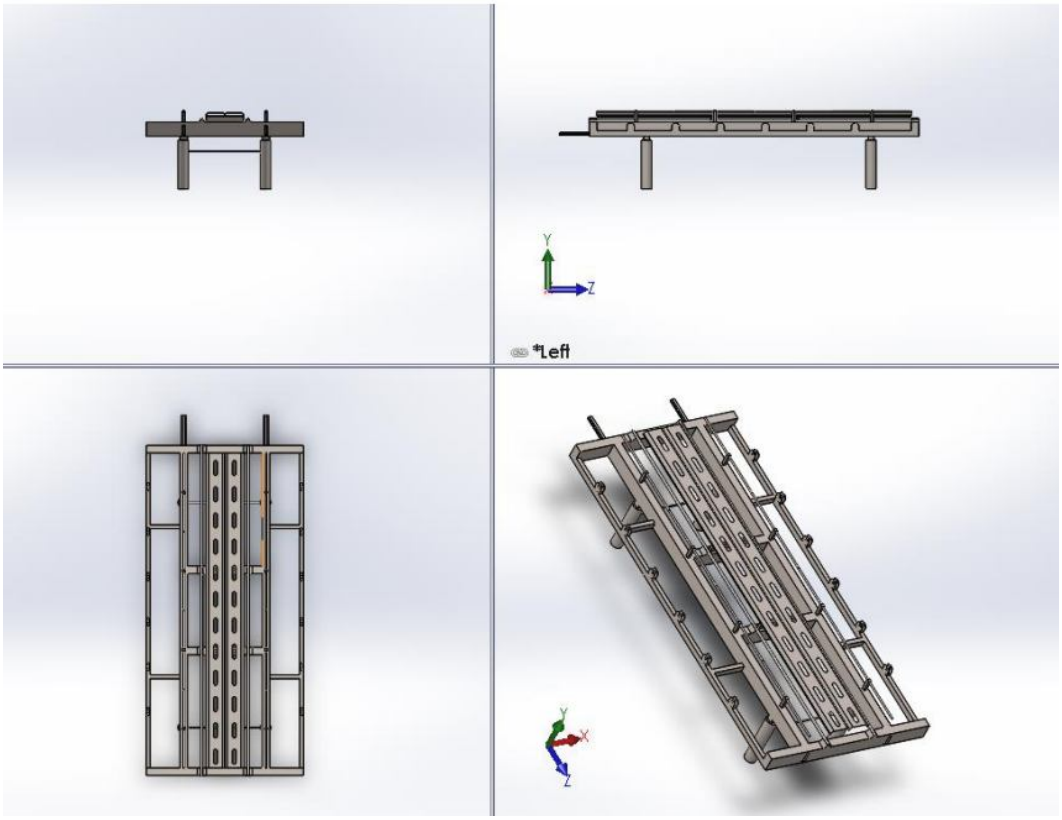


Fig 10 Orthogonal view of wedge cam assembly

VI. ANALYSIS

ANSYS software is used to perform static structural analysis in order to determine the material's structural stability and stability is examined.

1) *Static Structural Analysis*

Static structural analysis in ANSYS is a method used to determine the response of a structure to various loading conditions without considering the effects of time. It helps engineers and designers understand how a structure will behave under different loads, such as forces, pressures, or thermal effects, and allows them to optimize the design for safety and performance. In ANSYS, you typically start by creating a geometric model of the structure you want to analyze. This can involve defining materials, assigning properties, and setting up the boundary conditions that represent how the structure is constrained or supported. Then, you apply the loads to simulate the real-world conditions the structure will face. The software then solves a system of equations based on the applied loads, boundary conditions, and material properties to determine the structural response. The results can include information on stress, strain, deformation, and other relevant factors. Static structural analysis is valuable in industries like aerospace, automotive, civil engineering, and more. It helps ensure that structures can withstand the forces they'll encounter during their lifecycle without experiencing failure or excessive deformation.

MATERIAL FOR STRUCTURAL ANALYSIS

A 201 annealed stainless steel is used as material and its material properties are used to done the structural analysis. 201 annealed stainless steel is selected for my design because of its properties 201 annealed stainless steel is a specific type of stainless steel alloy. Stainless steel is known for its corrosion resistance, strength, and versatility, and it comes in various grades.

MATERIAL PROPERTY OF 201 ANNEALED STAINLESS STEEL

Elastic Modulus 207000 N/mm^2 Poisson's Ratio 0.27 N/A Tensile Strength 685 N/mm^2 Yield Strength 292 N/mm^2 Tangent Modulus N/mm^2 Thermal Expansion Coefficient 1.7e-05 /K

2) *Analysis Of Healthcare Bed*

- Total Deformation

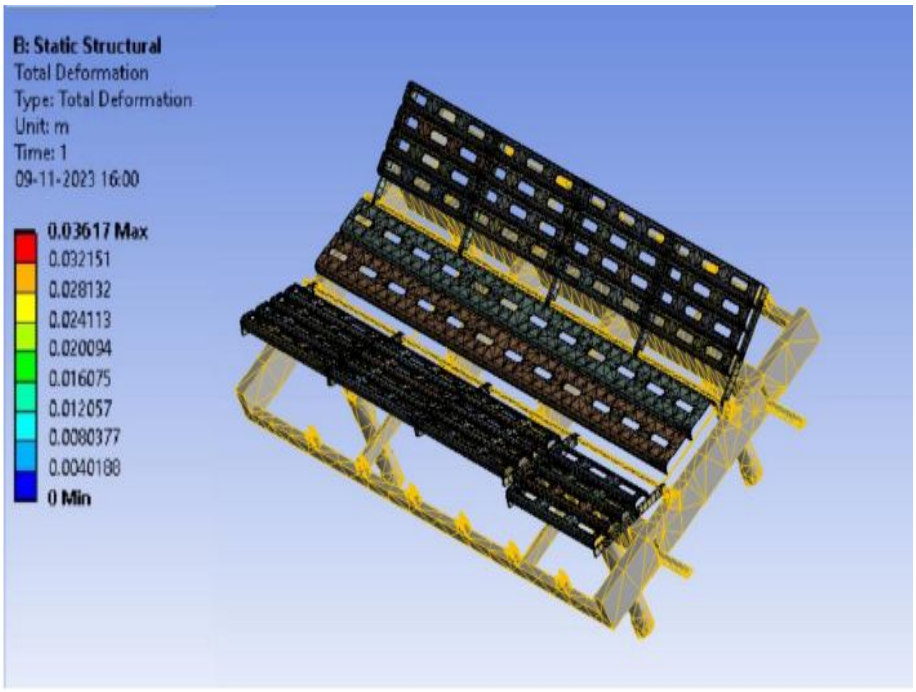


Fig. 11 Total Deformation

Deformation occurs in the range of 0 to 0.02 metres when the bed is subjected to a 100N load. The component's primary location is deformation-free. In follower, a maximum deformation of 0.02 metres is accumulated. The individual block is given support in order to locate the deformation fixed

- Volume Of Force Acting

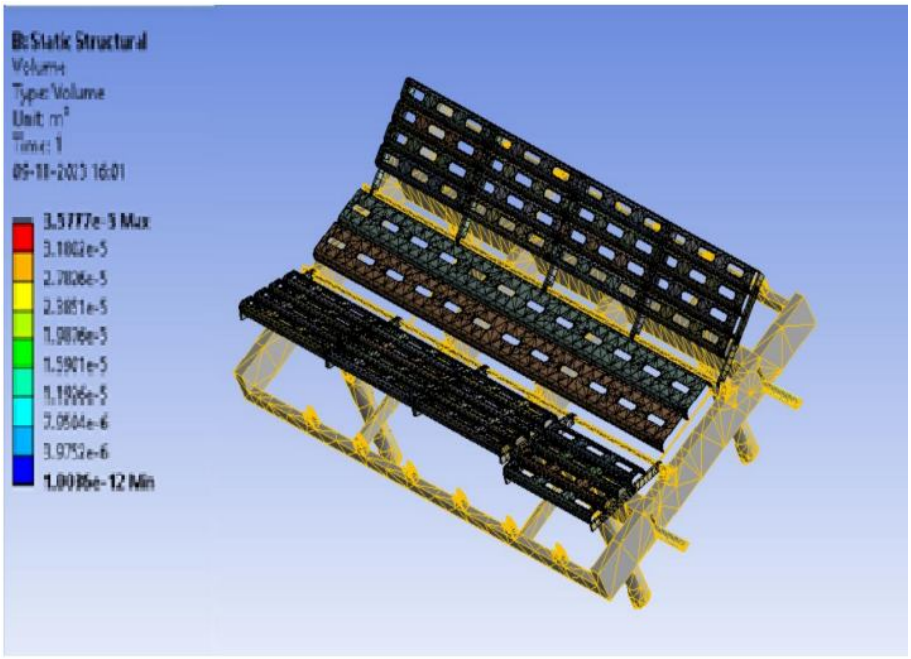


Fig. 12 Volume of Force Acting

In material, applied force takes up specific volume within the range of 1x10^-6 to 3.577X10^-5 m^3. The guide rod is under a lot of force. Comparatively less force is applied to other components. There is relatively little force transfer from bed to wedge cam

- Equivalent Elastic Strain

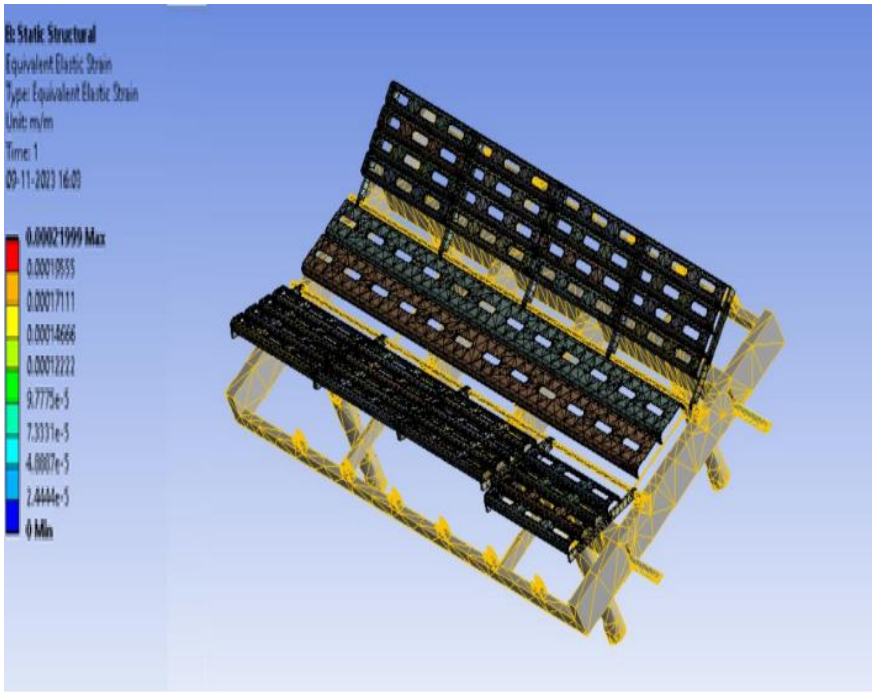


Fig. 13 Equivalent Elastic Strain

Elastic strain is calculated by the software for a given force. From 2.44e-5 to 0.0002, the elastic strain falls within this range. Majority of the component does not experience strain. Greatest tension within the bed since there is a movable joint present

- Maximum Stress

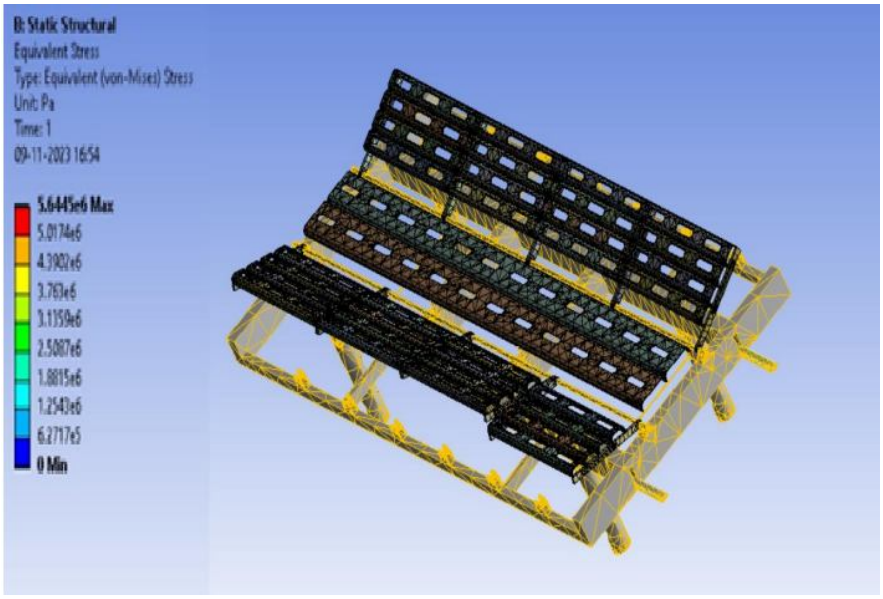


Fig. 14 Von -Mises Stress

The maximum stress that a material can experience is known as the von Mises stress. 6.27X10^5 to 5.644X10^6 Pa is the range of the van Mises stress. Due to the guide pin's fixed ends, the maximum stress is acting on it

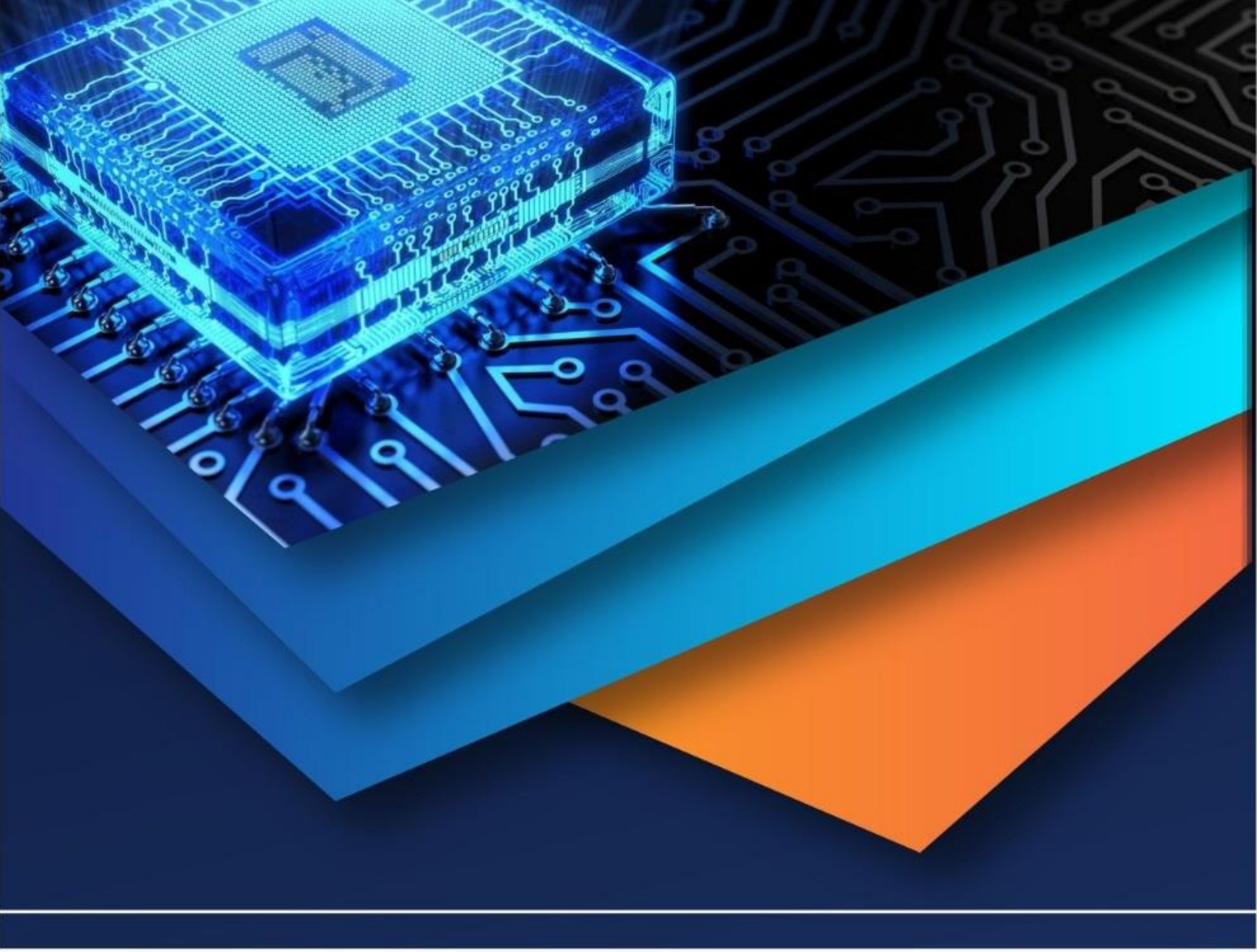
VII. CONCLUSION

An ergonomic healthcare bed has been designed and thoroughly analyzed to successfully address the problem of healthcare professions need to lateral tilting and rotation of the patients. The apparatus is designed to lateral tilt and rotation of the patients without the direct involvement of healthcare professions. The size of the bed is fixed as standard 2133mm in length. Bed included with side guard to protect the patients from falling down while tilting and rotation. The bed is composed of stainless steel material whose density is 7.9 g/cm³. The device's feasibility for physical dvelopment are determined by analysing the device's results. The von Mises stress, which ranges from 6.27X10^5 to 5.644X10^6 Pa for a given force of 100N, is the highest stress that a material can withstand.This range of 2.44e-5 to 0.0002 is where the elastic strain is found. The majority of the part is not under stress. When a 100N load is applied to the bed, deformation takes place in the range of 0 to 0.02 metres which is negligible. The primary location of the component is free from deformation. A maximum of 0.02 metres of deformation can accumulate in follower. Within the range of 1x10^-6 to 3.577X10^-5 m^3, force occupies a specific volume. The above values are calculated based on the fixed support that is given to individual block

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