PARALLEL MANIPULATOR

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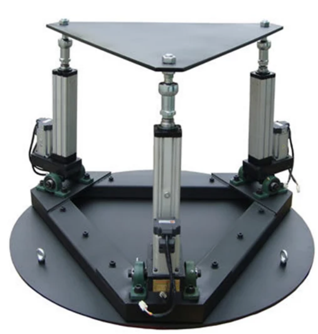
INTRODUCTION :

This is the era of automation where every field is trying to automate the tasks. Robots are one of the key structures used in automation. A robot may be defined as a machine that performs various complex and often repetitive tasks; guided by automatic controls. Industries are the areas where automation is geared up to increase productivity within a given time. One such industry is the photovoltaic(PV) industry. The global photovoltaic (PV) manufacturing community is on the verge of a resurgence in investment, development and innovation, a revolution that largely will be driven by technology. Robotic automation is a significant part of solar cell manufacturing. One of the tasks in the PV industry is to mount solar cells on the supportive base made up of glass or any other substrate with gentle handling. This process can be done by using parallel manipulators.

Mechanical systems that allow a rigid body (called end effector) to move with respect to a fixed base frame is a parallel manipulator. Parallel manipulators are robots composed of multiple closed kinematic loops. Typically, these kinematic loops are formed by two or more kinematic chains that connect a moving platform to a base. This kinematic structure allows parallel manipulators to be driven by actuators positioned on or near the base of the manipulator. It is very **compact** and has **high rigidity and strength**, hence can be used where compactness is required.

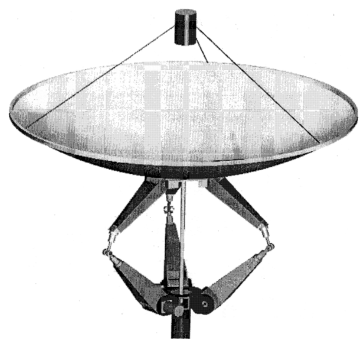


APPLICATIONS :

In the following figure, the Canterbury satellite tracker system uses a parallel mechanism for better orientation. The robot is made up of two modular units:

1) Slide : A Three-DOF Prismatic joint system with a fixed-leg length
2) Swing : A Three-DOF Revolute joint system.

The design allows emergency behaviour to lead to the saving in building, launching and operating costs for space applications. The reconfigurable configurations are considered as part of ultimate intelligent systems.



Another application of this manipulator is the NINJA-1 which is composed of legs based on a 3D parallel link mechanism capable of producing a powerful driving force for moving on the surface of a wall or glass. Welding tasks at the time of assembly as well as during maintenance are accomplished using a hybrid parallel robot developed for an international thermonuclear experimental reactor (ITER), which is a Vacuum Vessel.

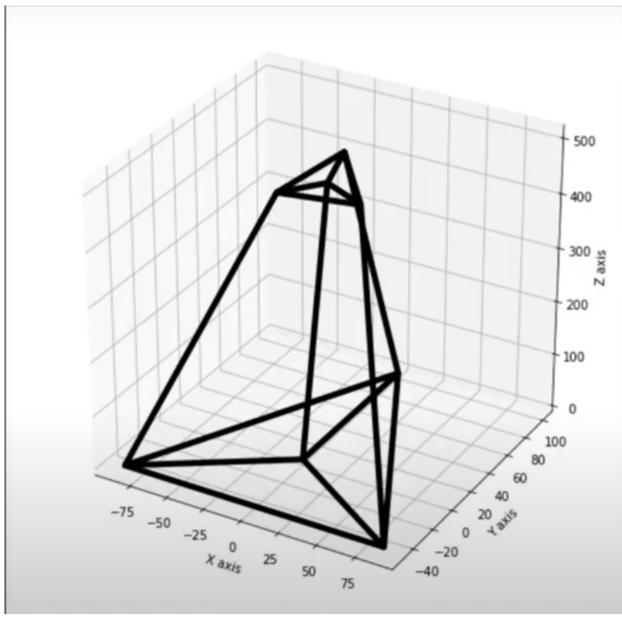
A flight simulator is a device that artificially re-creates aircraft flight and the environment in which it flies, for pilot training, design, or other purposes. Flight simulation is used for a variety of reasons, including flight training (mainly of pilots), the design and development of the aircraft itself, and research into aircraft characteristics and control handling qualities. To achieve this a 6-DOF 6 link parallel mechanism (commonly known as the Stewart Platform) is employed to achieve the most realistic environment.

METHODOLOGY :

Robotics :

Design of link lengths :

Link length calculations are done using the forward and inverse kinematics equations of the parallel manipulator. This is done to ensure the ideal link length setting for the given constraints.

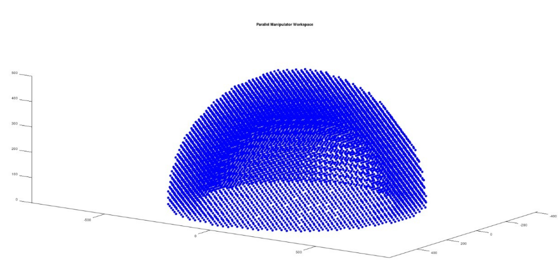


Estimation of force and torques :

This is done by calculating the dynamic forces and torque that would act on the members for a given payload and design the transmission systems and joints accordingly. This can be done by calculating the jacobian matrix. This way is ideal to ensure that the joints designed would never have to face any forces beyond its range.

Range calculation :

Using the dynamic forces and link length as constraints the workspace and the singularities of the manipulator is calculated. Once the singularities are located the necessary steps are taken to avoid them in maximum cases.



Mechanical Design :

Selection of Mechanical Drives :

A suitable transmission system has to be selected, designed and employed for providing actuation to the sliding and rotating joints in the Parallel Manipulator, Thus constructing a robust robotic system.

Design considerations for selection of the drive system :

Speed, High Strength, High Efficiency, Wear-Resistance(Reduction of friction), Mechanical Advantage(High reduction ratio), Reliability, Precession, Accuracy, Reduced Complexity, Ease of Assembly, Water-Proofing.

Design of ball bearings :

Selection and design of suitable bearings for the mechanical drives (active joints) and passive joints.

Design considerations for selection of the ball bearings :

Axial Thrust force, Radial Force, Speed of Operation, High Efficiency, Less Friction, Reliability.

Design of UV joints, Welded joints and Threaded Fasteners :

Selection and design of suitable UV joints, Welded joints and Threaded Fasteners,

Design considerations for UV joints, Welded joints and Threaded Fasteners :

Axial force, Radial Force, Shear Force, Bending moment, Speed of Operation, High Efficiency, Less Friction, Reliability.

Design of Structural Components :

Design of Structural components considering the von-mises (Maximum Distortion energy), Tresca (Maximum Shear stress), Rankine (Maximum Normal stress), Haigh (Maximum Strain energy) theory of failure and selection of suitable materials as per the stresses calculated.

Design considerations for Structural Components :

Normal Force, Shear force, Tangential Force, Torque, Bending Moment, Fatigue Stresses. Stiffness, Elastic.

Selection of Motor :

Selection of motor based on the required Torque, Speed, Maximum Power and Available Clearance.

Analysis of CAD model:

Ansys structural workbench :

The structural members of the robot are analyzed using Ansys structural to find whether the stresses due to the applied static loads in static conditions are within permissible limits and Fos is determined and design is changed if required FOS is not obtained.

Ansys transient workbench :

The structural members of the robot are analyzed using Ansys transient to find whether the stresses due to the applied static and dynamic loads in transient conditions are within permissible limits and Fos is determined.

Ansys multibody dynamics workbench :

The structural members of the robot are analyzed using Ansys multibody dynamics to find whether the mechanisms work according to the design.

Free Vibration analysis using Ansys modal workbench :

The structural members of the robot are analyzed using Ansys modal to find the natural frequency of the system and making sure no forces are applied at the natural frequency or multiples of the natural frequency.

Forced Vibration analysis using Ansys Forced Vibrations workbench :

The structural members of the robot are analyzed using Ansys Forced vibration to find the deformation and the stresses acting on the body at the applied frequency and amplitude of forced vibration.

Optimisation :

Topology Optimisation using Ansys topology optimisation :

- The topology of the structural members of the robot are optimised considering the stresses acting, cost, reliability, and duty cycle of the member.

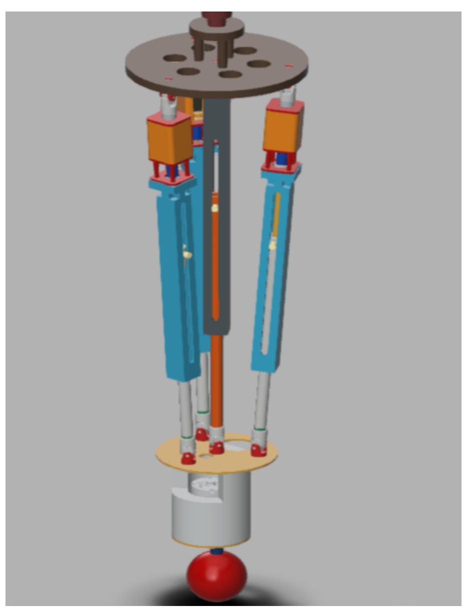
- Iteration of the design to make it easier to manufacture, economical and ensure that the design satisfies the design considerations.

Manufacturing Techniques :

- FDM 3d-printing,
- SLA 3d-printing,
- Milling,
- Turning,
- Broaching,
- Grinding,
- Laser Cutting.

EXPECTED RESULT :

- A 3d printed Robotic manipulator powered by DC motors will be made according to the designed Load, Reach, Degree of Freedom and Speed.
- The designed Robotic manipulator will be tested whether it could carry the designed load at the designed speed.
- The manipulator will be tested to carry 125% of designed load at 125% designed speed for a short period of time to make sure it can also handle slight overloads and over speeding.
- The manipulator will be tested whether it has the designed precession, resolution and accuracy using metrology equipment.
- The manipulator will be made to run for a prolonged period of time and the drift of accuracy of the system over a period of time can be determined.



FUTURE SCOPE :

- **Using the knowledge obtained from the previous works, a full scale parallel manipulator which could carry 20kg load is designed and manufactured.**
- It can be designed to be employed in the borewell child rescue system.
- It can be designed to be employed in the manhole scavenging system.
- It can be designed to be employed in the metrology lab for accurate positioning of the workpiece for laser interferometry measurement devices.
- It can be designed to be employed in the metrology lab for accurate positioning of the CMM probe.
- It can be designed to be employed in the assembly of the parts.
- It can be designed to be employed in 6-Axis milling and surface grinding.
- It can be designed to be employed in flight simulators.
- It can be designed to be employed in VR gaming simulators.
- It can be designed to be employed in industrial pick and place applications.
- It can be used for supper smooth stabilization of high speed cameras

REFERENCES AND LINKS

1) CAD file of the Parallel Manipulator -
https://a360.co/3fEuk0H

2) Parallel Manipulator Workspace Calculation -
https://drive.google.com/file/d/1PLrkGLN04Ew5wWm7XdZCh7DKIzVsFh4y/view?usp=sharing

3) Parallel Manipulator Inverse Kinematics Calculation -
https://drive.google.com/file/d/1h3pANAqy2II22VRu0e0FOufjpTuQkx2c/view?usp=sharing

4) The prototype of the parallel manipulator -
https://youtu.be/boE6m3LQRCA

5)Further references
https://drive.google.com/drive/folders/1jiAn3NNZavMBvNxvX9M6zHYTs4SikFbz?usp=sharing_eip_dm&ts=613f83ef