ABSTRACT

Parallel manipulators (PMs) have been the subject of study, of much robotic research during the past three decades. A parallel manipulator (PM) is a closed loop kinematic chain mechanism, that is connected to the base via multiple independent chains. Parallel manipulators can provide several advantages over serial manipulators in terms of low inertia, high stiffness, high rigidity and accuracy. These advantages arise due to the presence of kinematic loops within the manipulator, that allow the load to be transmitted to the ground via multiple chains. However, these kinematic closed loops cause the workspace of the parallel manipulators to be severely limited. Apart from the workspace, parallel manipulators also have some disadvantages such as their complicated structure, high cost and major challenge for their analysis and control.

To overcome the above disadvantages, the development of parallel manipulators less than 6-DOF has been accelerated. However, the analysis of the PM is complicated, because of the constraints and various singularities. As a result, PMs are not as popular as serial manipulators, because of lower mobility, workspace and complex structure.

The scope of this research work is to perform the modelling, simulation, dimensional synthesis and the kinematic, work volume and singularity position analyses of the three degrees of freedom PMs (TRIPOD and TRI-GLIDE). Since the mobility and workspace are quite complex in PM
design, the models were fabricated by considering those conditions, and the fabricated models were modeled and simulated using the ‘ADAMS’ software package.

In this work the following manipulators were modeled, simulated and fabricated. They are (1) 3-DOF (Prismatic-Revolute-Spherical) Tri-Glide manipulator with rigid links (actuating screws kept in a horizontal position), (2) 3-DOF (Prismatic-Revolute-Spherical) Tripod manipulator with rigid links (actuating screws kept in a vertical position), (3) 3-DOF (Prismatic-Revolute-Revolute) PM (actuating screws kept in a vertical position) and (4) 3-DOF (Prismatic-Revolute-Spherical) inverted tripod manipulator with rigid links (actuating screws kept in a vertical position).

The concept involved in this research work is based on the transformation of motion between the screw pair and the spherical pair, through links. The links are connected to the screw pair, which is actuated by stepper motors. The present work has been planned to model the parallel manipulators using the screw joints for very accurate positioning.

The Dimensional synthesis of 3-DOF parallel manipulators was performed based on geometrical parameters, and a single link movement is considered for the synthesis of the mechanisms. The dimensional synthesis was taken into account for determining the suitable dimensions of mechanisms by the logical approach. A comparative study was carried out between the TRIPOD and TRI-GLIDE Parallel manipulators, based on the mobile platform tilt, work volume and singularity positions. The work volume
was calculated using the PAPPUS-GULDINUS theorem. The general geometrical singularities are simulated using ADAMS, and compared.

Experiments were conducted for the position analysis and the angular tilt of the mobile platform along x-axis and y-axis and they were found by actuating the links of the manipulators. A set of kinematic equations were formulated for each one of the parallel manipulators, according to the type and degrees of freedom involved. Both forward and inverse kinematics equations are derived for the 3-PRR and 3-PRS Parallel manipulators. The Forward kinematics of the 3-PRS parallel manipulator is solved using MATLAB. A user interface is developed to actuate the actuators. Once the input is given, the software (C and JAVA) calculates the linear displacement of the nut and the number of rotations of the screw, which will be useful for giving the pulses to the stepper motor. The platform of the manipulator can be tilted to different angular positions, by giving suitable number of pulses to the motor.

In order to confirm the results obtained by the experimental and analytical method, ADAMS was used for solving the kinematic problems involved. The Tri-Glide and Tripod manipulators were created in ADAMS based on the fabricated models. The models were simulated for the displacement of the nut and the angle of tilt / rotation of the mobile platform about the x and y axes. The results obtained by the three methods are discussed and analyzed. By conducting kinematic simulations, various parameters like the force, position, angular tilt and torque with respect to the simulation time, are obtained through graphs.
In a conventional drilling machine, drilling an angular hole requires special fixtures for each specific angle. In the present work, the tripod parallel manipulator mechanism has been modified to an angular drilling machine, for performing angular drilling operations. The mobile platform of the inverted tripod was used as a cutting tool table to attain the required angular tilt. In the case of the inverted tripod, apart from the kinematic and workspace analyses, a finite element analysis was also performed, to check whether the maximum induced stress is within the allowable limit. The links and mobile platform were considered and a structural analysis was performed for the maximum stress and deflection, using ANSYS (Workbench) by specifying the load conditions.