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### Design of Cable-Based Manipulator

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**Abstract** – Developing technology and making technological innovations, a part of human life, have become a necessity in these days. Because of man's limited physical strength, human controlled machines have been developed for jobs that require strength and continuity. With evolving technology, these machines are available to use in many areas including primarily in industrial, medical, home electronics and defense industries. In these different fields, the need for this machine has been the driving force for development of parallel manipulator. As a result of integration of this machine and automation systems, concept of today's robots has been formed. To use in different fields, robots, that have serial and parallel working system according to mechanical structures, have been developed. Importance of the parallel manipulator and evolutions of the systems using this mechanism are discussed. According to the usage of these systems on the importance of parallel manipulators are discussed. In this study, general structure of cable based parallel manipulator which has 6 degrees of freedom has been introduced. Firstly analysis and modeling of the manipulator has been done and then mechanical design of parallel manipulator has been realized. While creating the system, a model based on the Stewart platform mechanism was used. Results of the simulation related to cable based model are presented in the study.

**Keywords -**  
Parallel manipulator,  
Stewart platform,  
Cable base manipulator

## 1. Introduction

Parallel manipulators are becoming more popular although serial manipulators have high movement capability and wide usage area. The main problem in serial manipulator is vibration and twisting which are increasing during overload or high speed. Parallel manipulators are frequently used in many industrial applications that require high precision, because parallel manipulators have high load carrying, durability, reliance and

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accurate positioning capabilities. Parallel mechanisms are used in industrial areas like game simulators, oil platforms, flight simulators and transportation.

Development of parallel manipulator started in early 1960s. Stewart has been developed parallel manipulator to use as flight simulator. After 1980, more people interested in parallel manipulator and it has been used in many different areas like medicine, transportation, space exploration etc. Nowadays they are used to develop high precision work benches.

In parallel kinematic manipulators load is shared by parallel arms connected to the fixed plate so it has advantages compared to serial manipulators, in certain applications like more load capacity, low to be inertia, more rigid structure, more easily controlled. Parallel robots have more complex kinematic loop equations [4].

Parallel manipulators are available in different configurations. One of them is symmetrical manipulator. The number of degrees of freedom in symmetric manipulator is equal to the number of legs and total number of cycles at the same time. Another one planar parallel manipulators having two or more kinematic joint, occurs when the planar parallel manipulators act on a shared platform. Planar parallel manipulators had led to today's cable-based parallel mechanisms [5].



Figure 1 Stewart Platform [6]

In 1965, Stewart works in 6 DOF parallel platforms, it proposed to be used as a flight simulator. Stewart platform with six degrees of freedom as shown in Figure 1, consists of the six chamber, the six joint, six general joints [5].

## 2. Hexapod Parallel Manipulators

Hexapod is one type of parallel manipulator with minimum positioning error. In figure 2, hexapods are shown having different number of actuators [5].

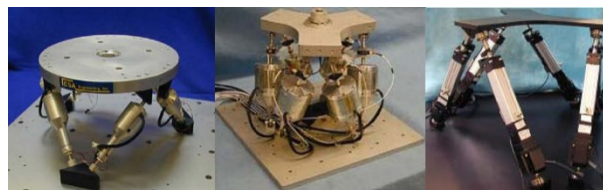


Figure 2 Hexapod Parallel Manipulator Types [3]

## 2.1 Cable – Based Robots

There are many applications of cable-based parallel manipulators: cutting, grading, shaping, handling and positioning of the plate. Cable-based parallel manipulators carry plate with “n” cable and “n” engine. Cable based robots have wide work area, due to fast mobility and easy reproducibility. [2]

Cable - based parallel manipulators has the same basic structure with Goughan - Stewart parallel manipulator. Figure 3-b shows the standard Stewart platform. In Figure 3-a shows a cable-based parallel manipulator.

Typical cable-based parallel manipulators, is formed by connecting cables to plate instead of joint legs. The plate movement is controlled by actuators that fixed on or mounted on system. [6]

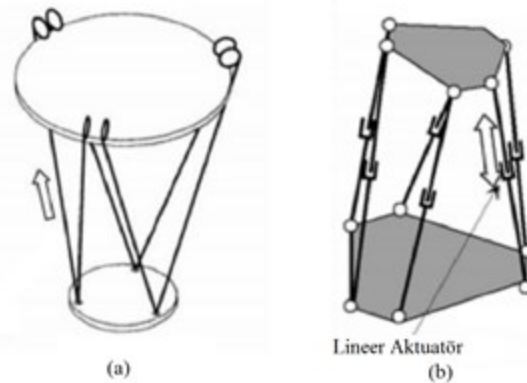


Figure 3 Parallel Manipulator Types, (a) .Cable - Base Parallel Manipulator (b) Gough-Stewart Parallel Manipulator [6].

The disadvantage of parallel mechanisms is limited workspace because of limited movement capability of the piston. Most of the researches were carried on cable-based Stewart platform mechanism. The difference of this mechanism from standard Stewart platform is to use cable instead of actuator pistons. Parallel cable, cable-based robots called Stewart platform, has wider mobility of working space than standard Stewart platform due to cables in the mechanism.

### 2.1.1 Advantages of the Cable-Based Robot Systems

Cable based robot system provides better balance between work space and consistency requirement than typical parallel and serial robots. Through light moving parts (cables) and constant heavy parts (motors and controllers), they have high load-weight ratio and low inertia characteristics. Also with a little change in cable system, it can be used many different applications [6].

### 2.1.2 Disadvantages of the Cable-Based Robot Systems

Although many advantageous aspects, many difficulties are encountered in the development of cable-based manipulator design. Geometric shape of the system may cause interference of cables. Because of physical properties of cable, vibration, stretching and sag problems can occur [6].

### 3. Study of Simulation

In this section of the study, we focused on the design of control for the cable based robot to be simulated. For design and the optimization of the system structure, creation of real-time simulation system has been tried to be. Solid model of the system is shown in Figure 4.

#### 3.1 Design

In this study, design model of the system prepared with solid modeling program and stretching-force graphics depending on static analysis, displacement and motor motion are obtained from this model.

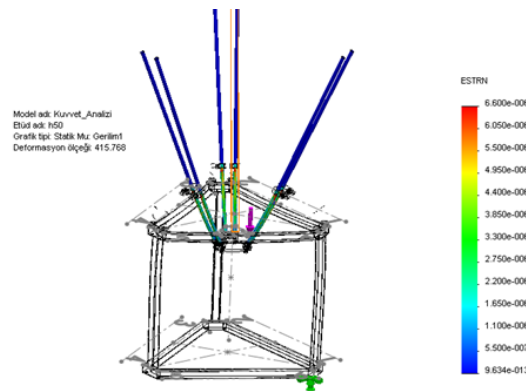


Figure 4 Deformation of cables with the effect of force applied to base.

Base of the system designed from aluminum material. Different system designs are created under different forces with steel cables, nylon and PVC cable. When designs being examined, the steel material observed to be very low amount of deformation compared to the nylon and plastic materials, however this heavy material cause strain in the winding and affect engine force negatively. Although plastic material is lighter than steel material, deformation in the material affects operation of the system. Nylon (polyamide) material is more favorable to other materials for the operation of the system under the forces applied.

#### 3.2 Motion Analysis

Position curve of the moving base is shown in Figure 5. In the system, movable base can change position in a limited area adhering to positions of motors. The main reason is that moving base on the system (under the influence of gravity) provides tension in the cables connected to the motors.

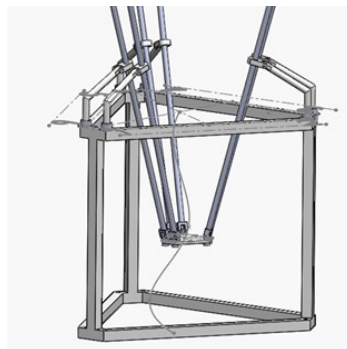


Figure 5 Position change of moving base

The position control of the system has been created with the help of graphics program in Figure 6. The system created in design program can be controlled in X, Y and Z axes.

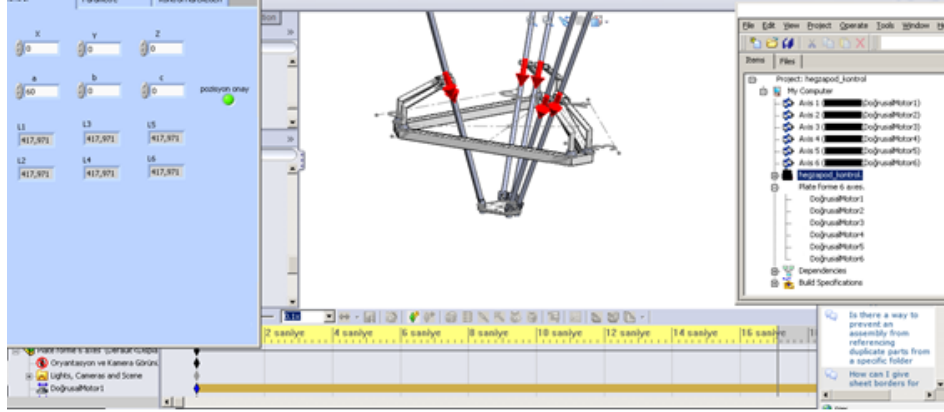


Figure 6 Simulation control of base with a graphic program

#### 4. Result

In the design of prototype, cable robot mechanism has been created by using six stepper motors and pulley system. System table is formed on the principle of free movement. In the system, positioning is achieved by using a graphical program block. The motion of the plate to the desired position in the workspace is obtained from the design program. System movement has very broad work space, compared to Stewart Platform. Along the Y-axis moving table can move in the X and Z axis. The main reason is that cable tension of the system can be obtained by adhering to the gravity only. System created with 6 cables can change position under the influence of gravity in a narrow area. This also causes certain problems in the position control of the system. Keeping in tension with the help of cables from the bottom of the base is expected to eliminate the positioning problems at the same time. If the system in this case the held in tension from bottom of the table, it will be more stable in position and its work space will be higher than its free position.

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