Chapter 2

Kinematic Concept and Mechanical Design

2.1 Introduction

A parallel kinematic robotic prototype was designed and manufactured. The robot will utilize a mechanism of positioning a point on the x-y plane. The system consists of two actuators. A stepper motor drives each actuator. As shown in figure 2.1, actuators *a* and *b* are of variable lengths, *la* and *lb*. Controlling the length *la* and *lb* will lead to positioning the point linking both actuators certain place on the x-y plane.

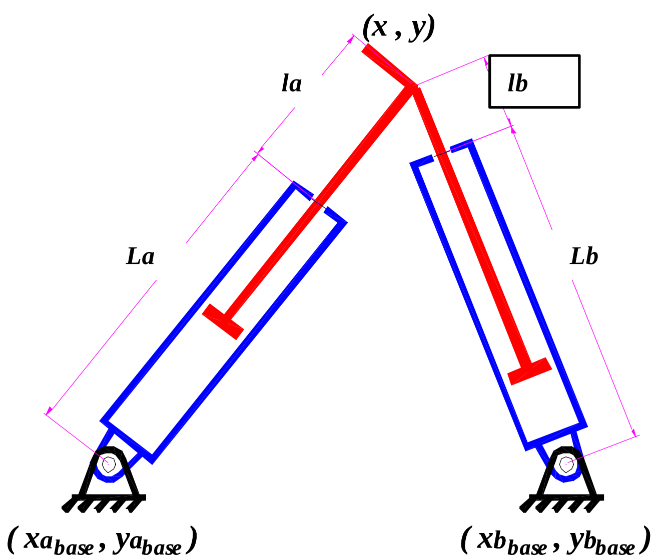

Figure 2.1: Simple 2D sketch for the mechanism to be designed

The variability of the actuator length is based on the idea of using nut-screw system. The rotation of a stepper motor is transmitted to the screw. Rotating the screw will lead to linear motion of the nut. The speed of the nut must be a function of motor speed, the design of the screw, and the transmission ratio.

The nut is moved a distance $p=1/n$ per each revolution of the screw, n is the number of threads per unit length of the screw. Figure 2.2 is for a nut-acme screw system. The distance p is equal to the pitch of the screw.

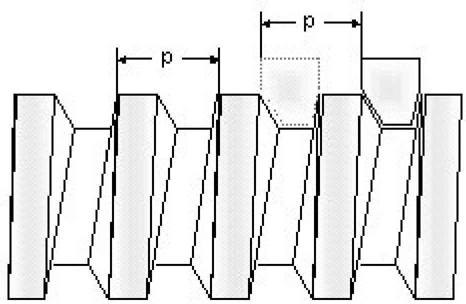

Figure 2.2: Nut-Acme screw System, the distance cut by the nut per each revolution of the screw is the same as the pitch of the screw.

If the change of the actuator length is ΔL, the total distance cut by the nut, then the number of screw's rotations that provides this displacement is found as follows:

Number of rotations = $\Delta L/p = n\Delta L$ (2.1)

Let's assume a transmission ratio that includes the gearbox and the transmission belt equal to $R : 1$, the motor shaft must rotate R times so that the screw rotates once.

Number of revolutions = $Rn\Delta L$ (2.2)

That is equal in degrees to 360 $Rn\Delta L$ (2.3)

For a stepper motor cutting 1.8^o per step,

$N = 200\ Rn\Delta L$ (2.4)

Where N is the number of motor steps. This information will set the base for the analysis of the kinematics of the motion conducted in chapter 4.

2.2 Details of actuator design, manufacturing, and assembly

The actuator consists of the following main parts: Housing - Bearing - Bearing Stopper – Nut - Outer Tube - Protruding Tube - Screw Shaft - Nut constraining path - End block.

The details of design, manufacturing and assembly of each part are discussed as follows:

1. Housing: The housing function is to hold the bearings, fixing the motor and the motor shaft is coupling whit the screw shaft in this housing . It is made of aluminum bar with 45 mm external diameter. The bearing housing has two Internal diameters:

- large internal diameter 28 mm diameter, 7mm from both sides of the housing, a distance equal to the bearings thickness.
- Smaller internal diameter 25 mm diameter, the rest of the housing length, to result in fixation of the bearings.

The outer tube from one end is fixed to the bearing housing and on the other side it is fixed to the motor. Between the bearing and the side that the motor was fix there are the coupling area. this coupling area has length of 45mm. On the side that the motor was fix the cylinder whit 75mm diameter and length of 5mm. The total length of housing is 95mm.

2. Bearing: Bearings are used to constrain the movement of the screw in the radial direction.. Bearings will allow rotation of the screw with the lowest possible friction. The bearing code selected is 6058 with inner diameter 12 mm and outer diameter 28 mm.

3. Bearing Stopper: It is the part that works with the housing to fix the bearings and stop the screw from moving in the axial direction. A bolt is fixed after screw pulley to aid in fixing the screw.

4. Nut: The nut is assembled around screw shaft. It is made of brass bar with three different diameters. The inner diameter is 12 mm. The small outer diameter is 18 mm and the larger outer diameter is 25 mm. The Nut slides in the constraining path. Movement of the nut is attained by the rotation of the screw in both directions.

5. Outer Tube: It is a case made of clear plastic with 38 mm inner diameter, 32 mm outer diameter and 200 mm length. One side of the tube is fixed with bearing housing and the other side is fixed with end block. It works with a bolt and a bearing stopper to constrain motion in the axial direction

6. Protruding Tube: A 150 mm long tube mounted on the small outer diameter of the nut. The other side is set on end block. It is consists of clear plastic tube which has an inner diameter of 18 mm, and outer diameter of 25 mm. It is 180 mm long. The Protruding Tube is move outside and inside depending to nut movement.

7. Screw Shaft: It is made of brass bar with 12mm diameter. The part of it covered by the bearing housings is a normal cylindrical tube while the rest is an acme power screw with 3 1/3 threads per cm. It takes rotation movement from the motor shaft by coupling.

8. Nut Constraining path: A path made on the outer tube used to prevent the nut from rotating. The length of this path is 15 mm.

9. End block: It is made of Aluminum. It is placed on end of the outer tube. It used to hold the protruding Tube. It is of circular shape and has an outer diameter 45 mm and inner diameter 26 mm. The area of contact between Protruding Tube and End Block is small to reduce the friction.

The overall actuator design is shown in figure 2.11. The functioning of the actuator can be summarized as follows:

The motor shaft is connected to the screw shaft by coupling that transmits rotation from the motor shaft to the screw shaft. The screw shaft is fixed on one side by two bearings placed 40mm from each other. These two bearings are fixed to the screw with the lowest possible friction. The housings and bearing stoppers work together to fix the bearings. The bearing stopper is a part of screw shaft itself. The protruding tube is attached with the screw by a nut. In order to allow the nut to move in axial direction it is required to prevent it from rotation and that is the reason of using nut constraining path. The protruding tube is fixed on the nut on one side and the other side is fixed by end block. The outer tube is used as a casing fixed to the bearing housing, and the end block. Minimum amount of friction is to be had between the elements with direct contact to each other: the outer tube with the protruding tube, the nut constraining path with the nut, and the protruding with the end block.

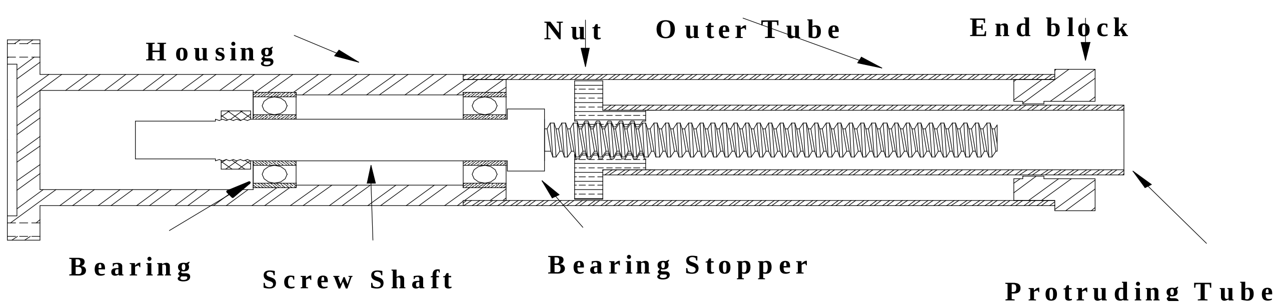

Figure 2.3: Overall actuator design.

2.4 Design of the connecting joint.

The joint is used to link the two actuators in a point, so that the point will move in the x-y plain. In order to decrease the friction between the two halves of the joint, a bearing and pin are used. The upper part of the joint is fixed to the pin by a thread. A 1 mm gap will be left between the two parts. The bottom part is allowed to rotate around the pin using a bearing. The bearing is fixed to the bottom half using a cap and a bolt.

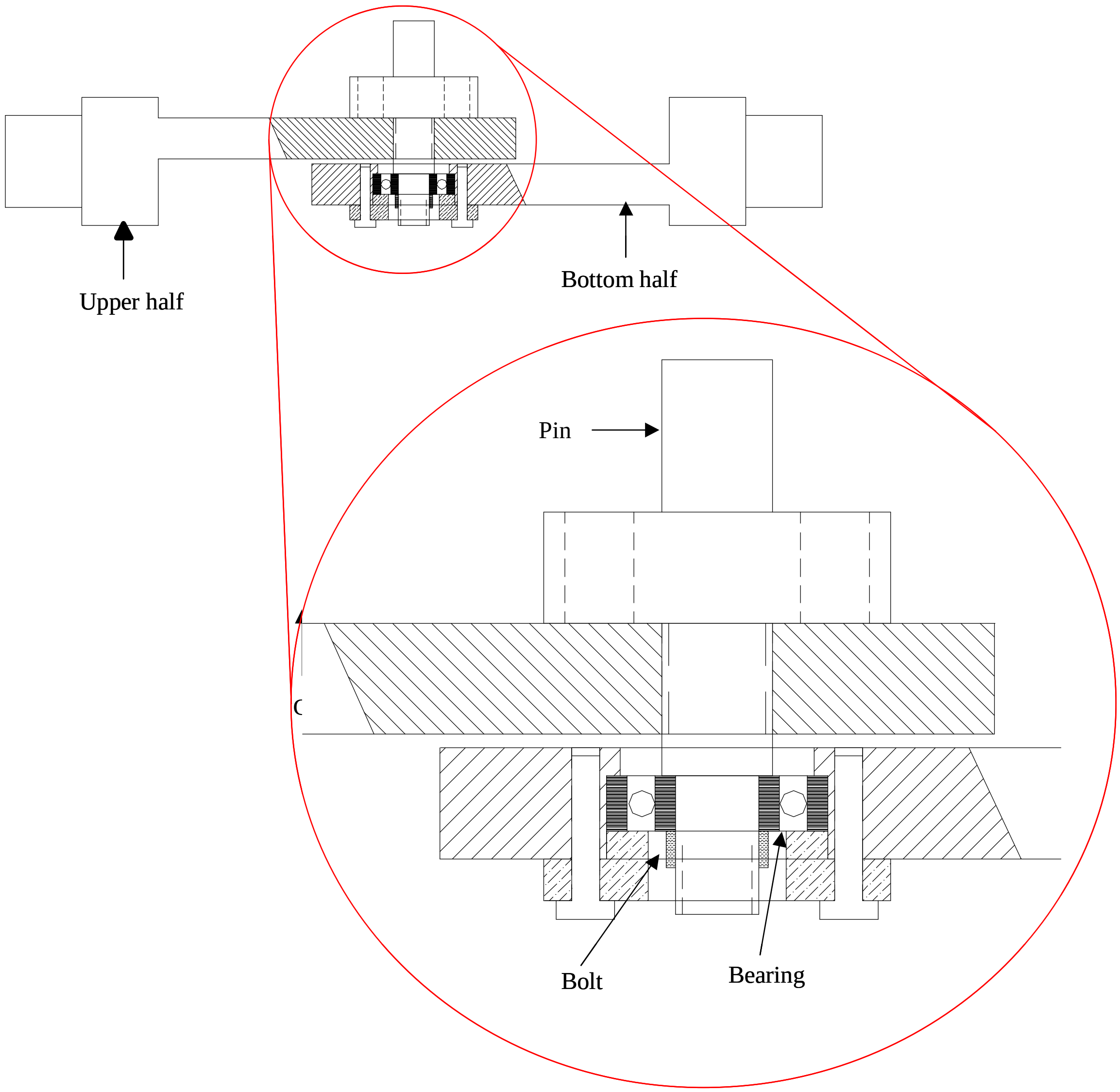

Figure 2.4: Design of the joint mechanism.

The joint's main parts are The Cap – The upper half of the joint - The bottom half of the joint and the pin.

1. Cap: It consists of a 16 mm diameter x 3 mm thickness upper cylinder and a 25 mm diameter x 2mm thickness lower cylinder. The cap is hollowed along its two parts having an inner diameter of 14 mm. There are two M2 threaded holes in the large cylinder to fix the cap with the bottom half of the joint. The cap material is aluminium.

2. Upper Joint half: A 100 mm cylinder. The first 15 mm has a 18 mm diameter. The second 15 mm has 25 mm. The rest of the cylinder has a 25 mm diameter with the material removed to a depth of 4 mm from above and 13 mm from below. An M8 hole was made 80 mm from the leading edge. The pin will pass by this hole. The material used is aluminium.

3. Bottom Joint half: It is a replicate of the other half with different hole dimensions. The whole is 14 mm diameter to a depth of 2 mm. The diameter steps to 16 mm until the end of depth to work as bearing seat.

4. Pin: A cylinder with four diameters from above: 8mm, 25mm, 8mm and 6mm. The depth of each diameter is 11mm, 8mm, 11mm and 10mm, respectively. The 25mm diameter part has two M5 holes that will be used to fix the end effectors mechanism to the upper joint half. The second 8 mm part is threaded as another fixation to the upper half. The 6mm part will go through the bearing. This part is ended by a thread to allow attaching a bolt that will hold the bearing from below.