2.5 Design of the pen mechanism.

The mechanism consists of a fixed plate, rotating plate, in addition to the solenoid and rubber string, as shown in figure 2.5:

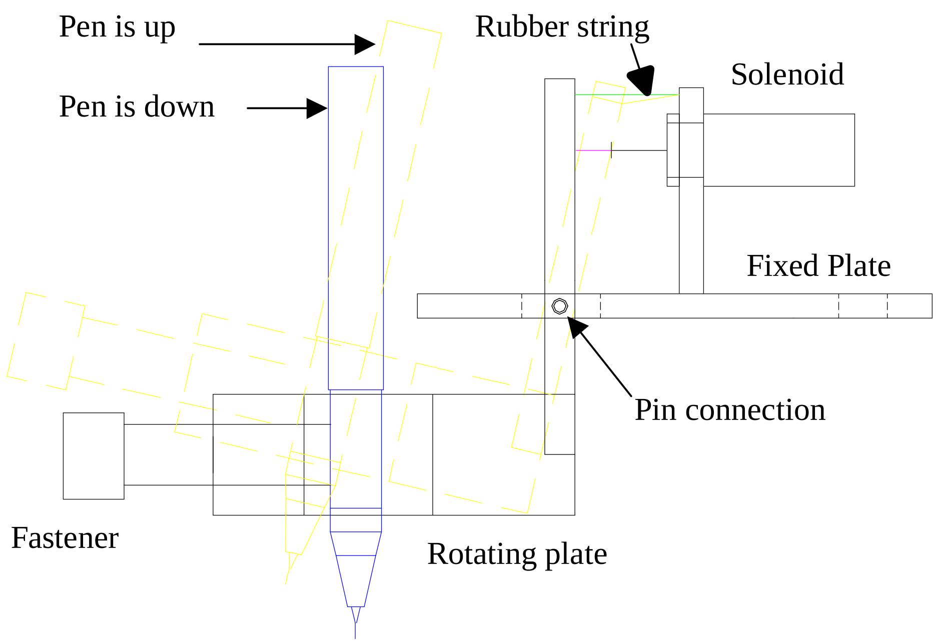

Figure 2.5: Design of the pen mechanism.

1. Fixed plate: A 85 mm x 35 mm plate that is installed on the pin discussed in the joint design using a 8 mm hole located 11.5 mm from the leading edge. It is fixed to the upper half of the joint using two M5 fasteners and is perpendicular to its axis. The solenoid is installed 40 mm away from the leading edge.

2. Rotating plate: L-shape plate attached to the fixed plate by a pin to allow its rotation. It consists of a 62 mm x 13 mm x 5 mm plate and 65 mm x 20 mm x 20 mm perpendicular plate, welded together. It has a triangle shaped hole used to fix pens of any size and shape. The pen is fixed using an M10 fastener.

When the solenoid is energized, the pen should be placed on the drawing plain. This implies that the 65 mm x 20 mm x 20 mm pen holder should be parallel to the drawing plain. When the solenoid is de-energized. The rubber string will pull the rotating plate rising up the pen from the drawing plain. The dimension of the pen mechanism where selected in such a way that the pen will not scratch the drawing plain when being rise up. This was done by selecting the least possible distance between the center of rotation of the plate and the drawing point.

2.6 Design of Jack mechanism

The purpose of designing a jack mechanism is to aid in a drilling system that will be used to make holes in predefined positions in a printed circuit board (PCB). While the drill will be fixed as an end effecter to the parallel manipulator, drilling will occur when the jack rise and lower the PCB.

The jack mechanism is a system in which the motion direction changes in two stages:

A nut screw system will translate the rotation of the motor into horizontal motion along the axis of the screw. Horizontal motion will result in rising the PCB holder a certain distance upward. Figure 2.6 demonstrates the mechanism that will be used to accomplish this purpose:

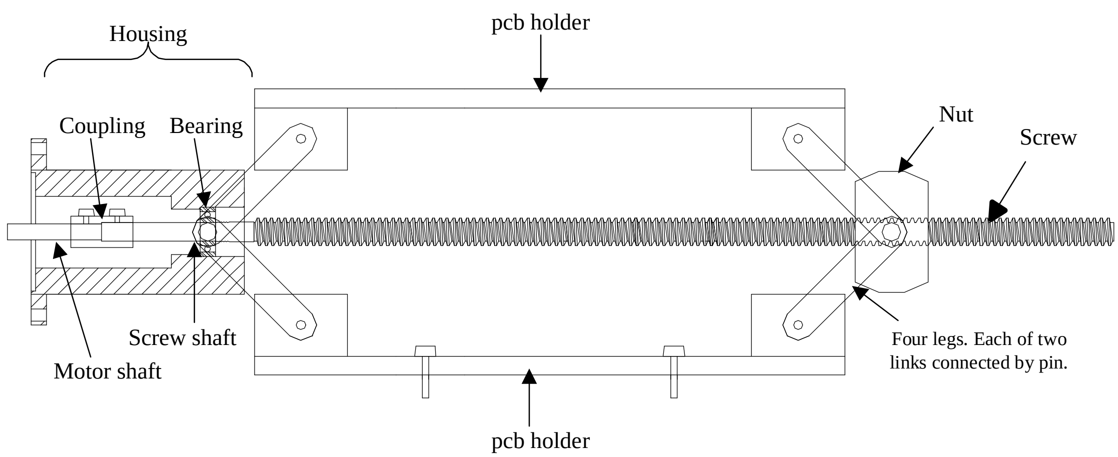

Figure 2.6: Design of Jack mechanism.

As shown in the figure, the mechanism consists of the following parts:

Base - PCB holder - Bearing and coupling housing - four pins - nut - screw - Eight links.

1. The base: A 175 mm x 128 mm x 6 mm plate. It has a 20 mm x 30 mm x 8mm leg in each corner. These legs are used to attach four links. The distance, perpendicular to the axis of the screw, between each leg is 100 mm. The base is made of plastic.

2. PCB holder: The same as the base plate, but with the distance between legs is 92 mm.

3. Housing: Similar to the housing in the actuator design, with the same diameters, but with the following changes:

- Single bearing.
- The housing is made of aluminum bar with 45 mm external diameter.
- On the side that the motor was fix the cylinder whit 75 mm diameter and length of 5 mm. The total length of housing is 57 mm.

4. Pins: The pin has two diameters: 6mm for a length of 37 mm and 3 mm for a length of 13 mm. The pin has a thread of 5 mm length from each side. The two pins fixed to nut have a length of 40mm for each. The two pins fixed to the housing have a length of 37.5 mm for each. The pin material is aluminum.

5. Nut: 20 mm x 40 mm part taken from 40 mm diameter brass cylinder. The nut has an M6 hole for the screw to pass into.

6. Links: Eight 10mm x 52mm x 4mm plates having two hole on each side with 3mm diameter.

Having two pair of links fixed to the bearing, which has no relative motion with the screw, while the other two fixed to the nut, which is translating on the axis of the screw, The PCB holder will rise up whenever the screw translates to toward the bearing. The PCB will be lowered when the nut moves away from the

2.6 Allowable drawing area

The allowable drawing area consist of all the points on the x-y plane that the controlled point can be placed at. The allowable area is found by satisfying the following conditions:

1. The area is constrained by the intersection of the four circles of the following radii: minimum length of actuator a La, minimum length of actuator b Lb, maximum length of actuator $a\ La + La_{max}$ and maximum length of actuator $b\ Lb_{max}$ as show in figure 2.6:

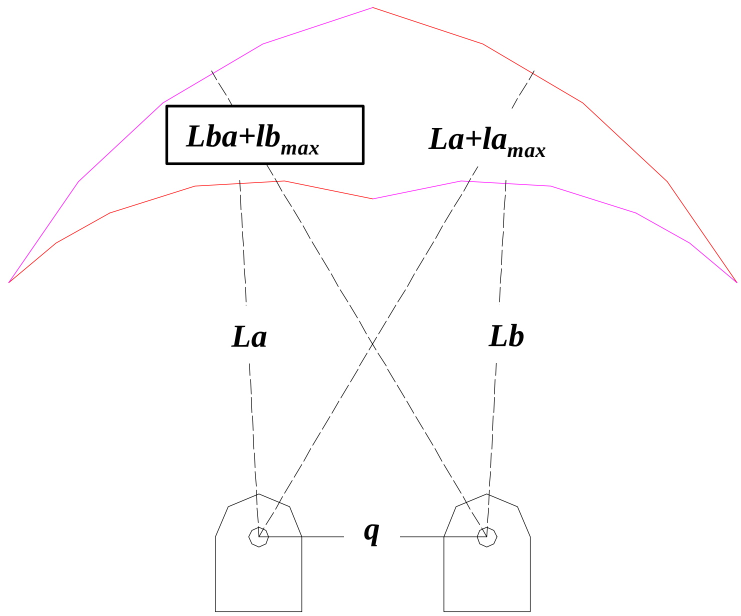

Figure 2.6: The drawing area is limited by the minimum and maximum lengths of the actuators *a* and *b*

2. The area is constrained by the how much angle the actuator holder is allowing the actuator to rotate. In our design this angle is equal to 90^o. Figure 2.7 demonstrates the constrained area satisfying the first two conditions. N

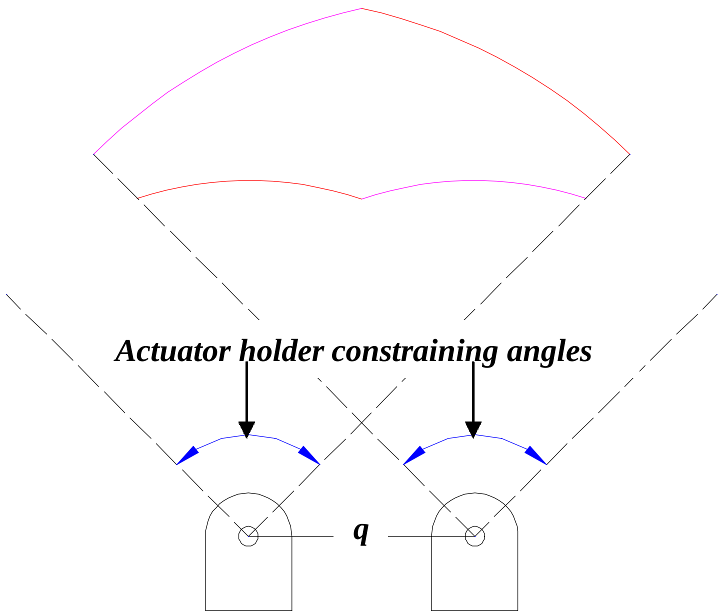

Figure 2.7: The drawing area is limited actuator holder constraining angle

The actuator holders can be rotated in such a way that we can make use of the whole area allowed by the first condition.

3. If the actuator lengths at the minimum allowable joint angle ξ is less than the maximum actuator lengths, the area will be constrained by the intersection of the two circles of radii equal to the minimum actuator lengths, and the two circles of radii equal to the actuator length when the joint angle is equal to ξ, as shown in figure 2.8. In our design, ξ has a value of 90^o

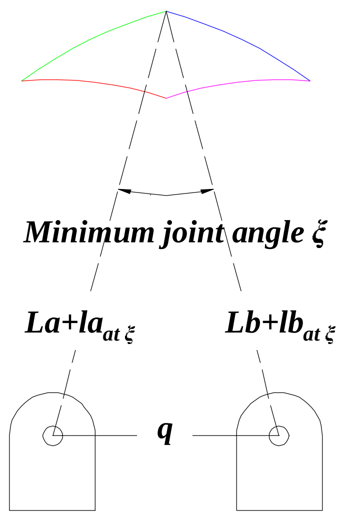

Figure 2.8: The drawing area is limited the minimum joint angle ***ξ***

1. The resulting area after satisfying the first three conditions would be the allowable area in case the controlled point was the point connecting the two actuators. However, the controlled point is at a minimum distance of 77.5 mm perpendicular on the axis of actuator a. The drawing area will be as shown in figure 2.90.

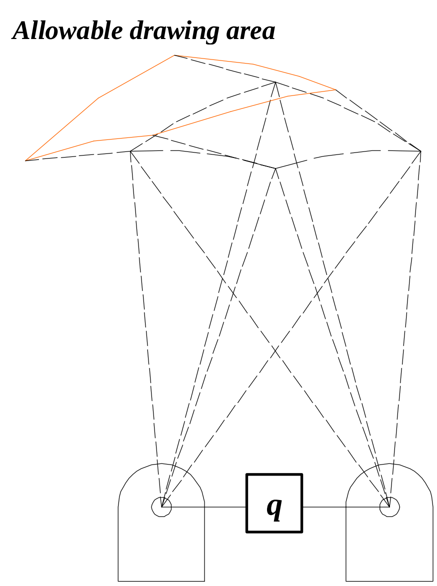

Figure 2.9: the final shape of the drawing area

This area would be used to set conditions on the inputs coordinates to the program controlling the robot, as going to be discussed in chapter 4. This area can be evaluated for several values for the distance separating the center of rotation of the actuators *q*, in order to select an optimum value for *q* as shown in figure 2.10. From the figure, we can notice that the effect of the ξ results in huge reduction of the area for q less than 242.6 mm. Q was chosen to be 245 mm. Actuators *a* and *b* will be rotated with respect to the positive x-axis –60^o and 60^o, respectively.

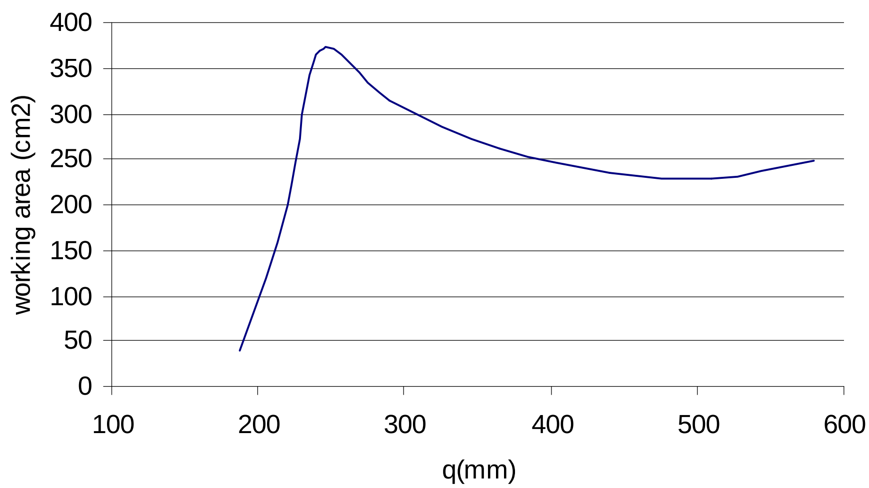

Figure 2.10: Optimization of the working area of the actuators.