An essential calculation which had to be completed before moving on to other analyses is that of the linkage lengths (most importantly Link1 and Link 2) and their corresponding “workable” area. In this analysis, we try to optimize the link lengths to maximize the workable area which can be sculpted at the tool bit. However, the link sizes should not be too large in order to minimize size and weight of the overall device. Thus, a balance must be stuck between optimum link sizes and maximum workable area.

At first, we must define how we express the workable area at the tool bit. From the *Matlab* plots results discussed in the CFP, we already know the general shape of these areas. They can be *approximated* as the area between two circular boundaries, one boundary of which is larger than the other. Thus, we define the outer or larger curved boundary as Rmax and the inner our smaller curved boundary as Rmin. The side boundaries of the workable area are approximated as straight vertical lines, and the distance between them is called Rangex. Thus, the workable area looks like the following (note: in reality, the origins of the radii should be different, but this is a very close approximation):

Rmin

Rmax

Rangex

With the workspace coordinates defined, we must also define the variables on the linkage design in order to optimize the linkage sizes. A number of variables are incredibly important to this analysis, and are identified and illustrated below:

LR

L3

L5

R

θ3-5

θ5

y

z

From the setup above, we can write the following geometric relationships between distances and angles:

(note: L1 , L2 and θ12 are not shown in the diagram)

We will create a virtual length called L’5:

L’5 = L5cosθ5

With that new virtual length, we can define the “reachable” length in the “z” and “y” directions stated above:

90 - )

90 - )

Since the “z” and “y” lengths described above are components of the R vector, we can compute the length of R simply as such:

Inserting all these variables and equations in a spreadsheet and optimizing the workable area based on links 1 and 2, the most reasonable option which gives us a large workable area while not overly extending the length of the links, happens when both links 1 and 2 are equal in length and measure 7 cm. The excel spreadsheet used in this analysis can be found in the Appendix.