RESULTS AND DISCUSSION

B. Geometrical parameters of recirculating wake

Previously, the five geometrical parameters of a recirculating wake were described which are C_X, C_Y, L_L, L_R, L_W. These five parameters describe the location and length of the recirculating wake region. The simulation has been done on COMSOL Multiphysics for both Square geometry and Circular geometry with unit dimension with n = 10.

To determine L_L , L_R, L_W a cut line has been taken horizontally through the centre of the unit square/circle. Then, along the cut line velocities in different horizontal locations have been plotted. It is observed that for a particular Reynolds Number, the uniform unit velocity decreases as we move to the geometry horizontally and at a point past the geometry it becomes zero or very close to zero. This is the point from where the recirculating wake region starts, so the distance between the end of the geometry and this point is L_L. Similarly, as we move further along the cut line the velocity increases to some value and then again decreases to zero or very close to zero. This is the point where the recirculating region ends and after that the velocity continues to increase. The distance between the end of the geometry and this point is L_R. Now, the length of the recirculating wake region L_W can be calculated as the difference between L_L and L_R. These value changes with variation in Reynolds Number (Re) and the ratio 'r' (r =s/d).

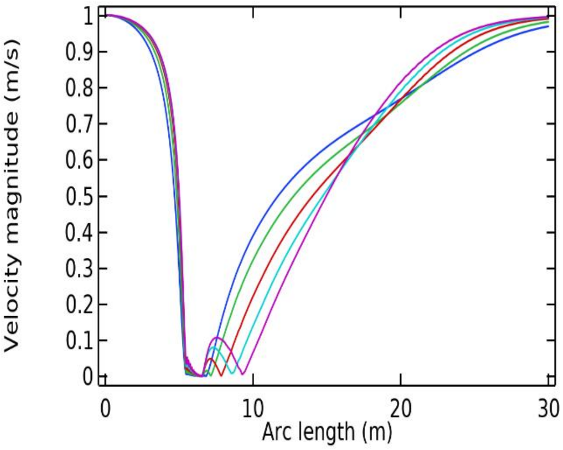
To determine C_X and C_Y, the center of the vortex has been visually spotted and a vertical cut line through it has been taken covering the vertical span of the computational domain. Then, along the cut line velocities in different vertical locations has been plotted. It is observed that for a particular Reynolds Number, the uniform unit velocity decreases as we move to the vertically. It is seen that there are two points where the velocity becomes zero or very close to zero. These two points are equidistant from the centerline of the geometry. The distance between the centerline and the point vertically is the value of C_Y. Now, as we have got the ordinate of the center of recirculating wake, if we draw another horizontal cutline through it and plot velocities along the line, we will find a point where the velocity is zero or very close to zero. The distance between this point and the rear of the geometry is the value of C_X.

Using the above methods in COMSOL Multiphysics these values have been calculated for both geometries. The variation of these values with Reynolds Number (Re) and the ratio 'r' (r =s/d) are shown below for both Square and Circular geometries.

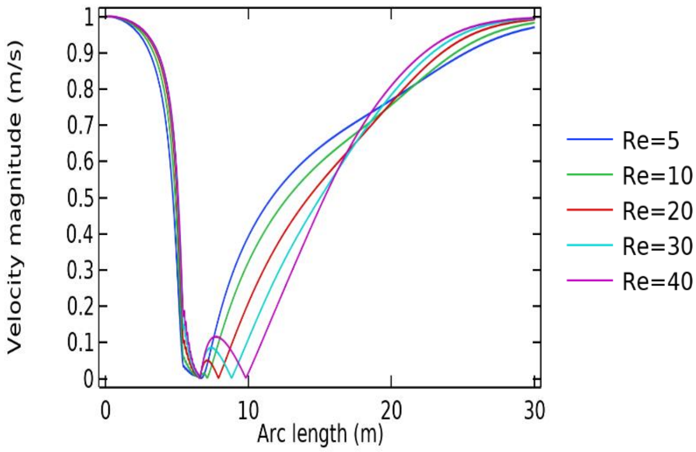
I. Square Geometry

The following figures show the velocity distribution along the length of the computational domain through the center of geometry for different Re values (Re = 5, 10, 20, 30, 40) and different ‘r’ values (r = 1, 10 100, 200, 500, 700) :

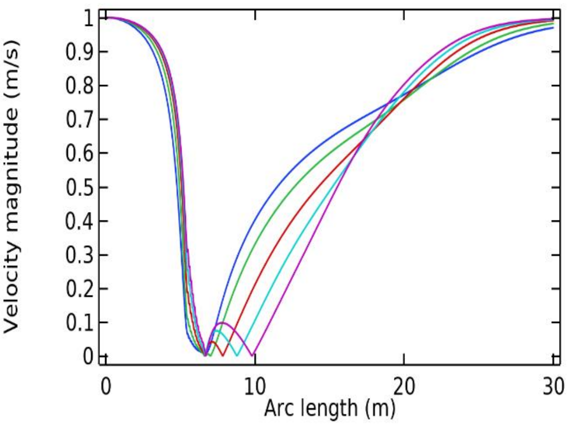
r = 1



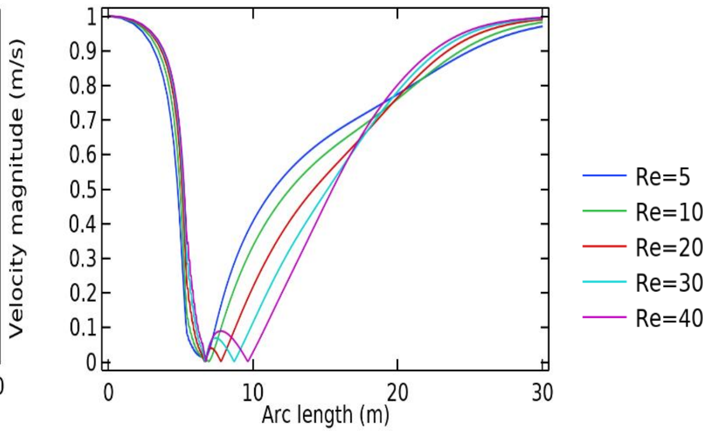
r = 10



r = 100



r = 200



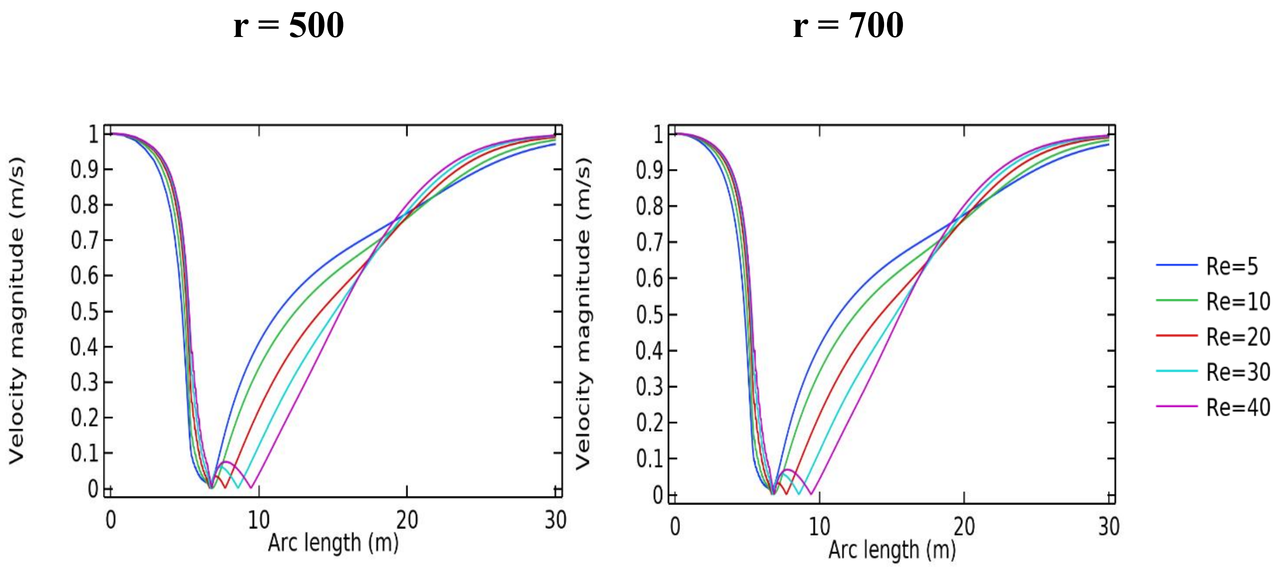
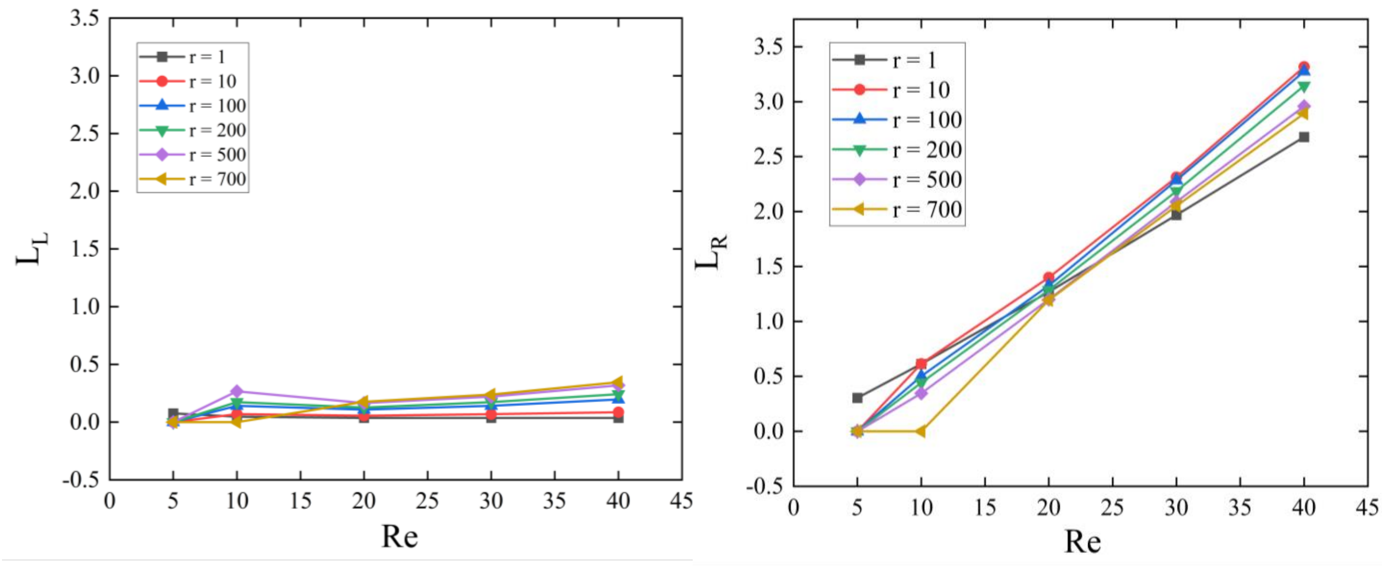


Fig. 1 : Velocity Distribution along the length of domain

From the above velocity diagrams the value of L_L and L_R can be calculated by identifying two stagnation points for a particular Re value and the length of the wake zone L_W can be calculated. Thus, different values of L_L, L_R, L_W are obtained for different Re and ‘r’ values. These values are plotted in OriginLab software and are shown below :



(a) (b)

Fig. 2 : Comparison for Re vs L_L , L_R for Square geometry for different r value

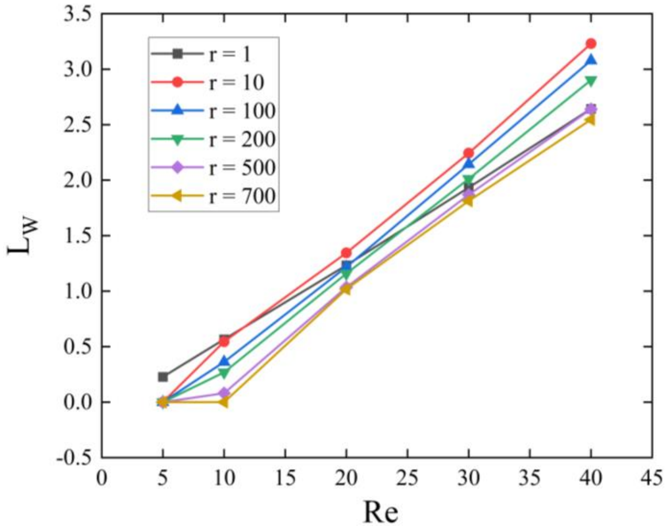


Fig. 3 : Comparison for Re vs L_W for Square geometry for different r value

From Fig.2(a), it is observed that the L_L value almost doesn't change with Re value and increases slightly with increase in 'r'. It is observed at lower Re value (Re = 5, 10) for high permeable flow i.e., 'r' = 500 or 700, L_L value is zero which necessarily means there is no recirculating wake zone formed for these flows. From Fig.2(b), it is seen the L_R values follow linear trend with Reynolds Number and from r = 10 to r = 700, the L_R values decrease for a particular Re value. It is also seen that for r = 700, the value of L_R at Re = 5, 10 is zero which means no recirculating wake zone formed as stated earlier. Similarly, from Fig.3 it is seen the L_W values follow linear trend with Re and from r = 10 to r = 700, the L_R values decrease for a particular Re value.

The next two important geometrical parameters are C_X and C_Y which helps to locate the center of upper vortex. As discussed earlier, these two are also found from velocity distribution at a particular Re and 'r' value from a defined horizontal and vertical cutline. The following figures show the variation of C_X and C_Y with Re value for a particular 'r' value:

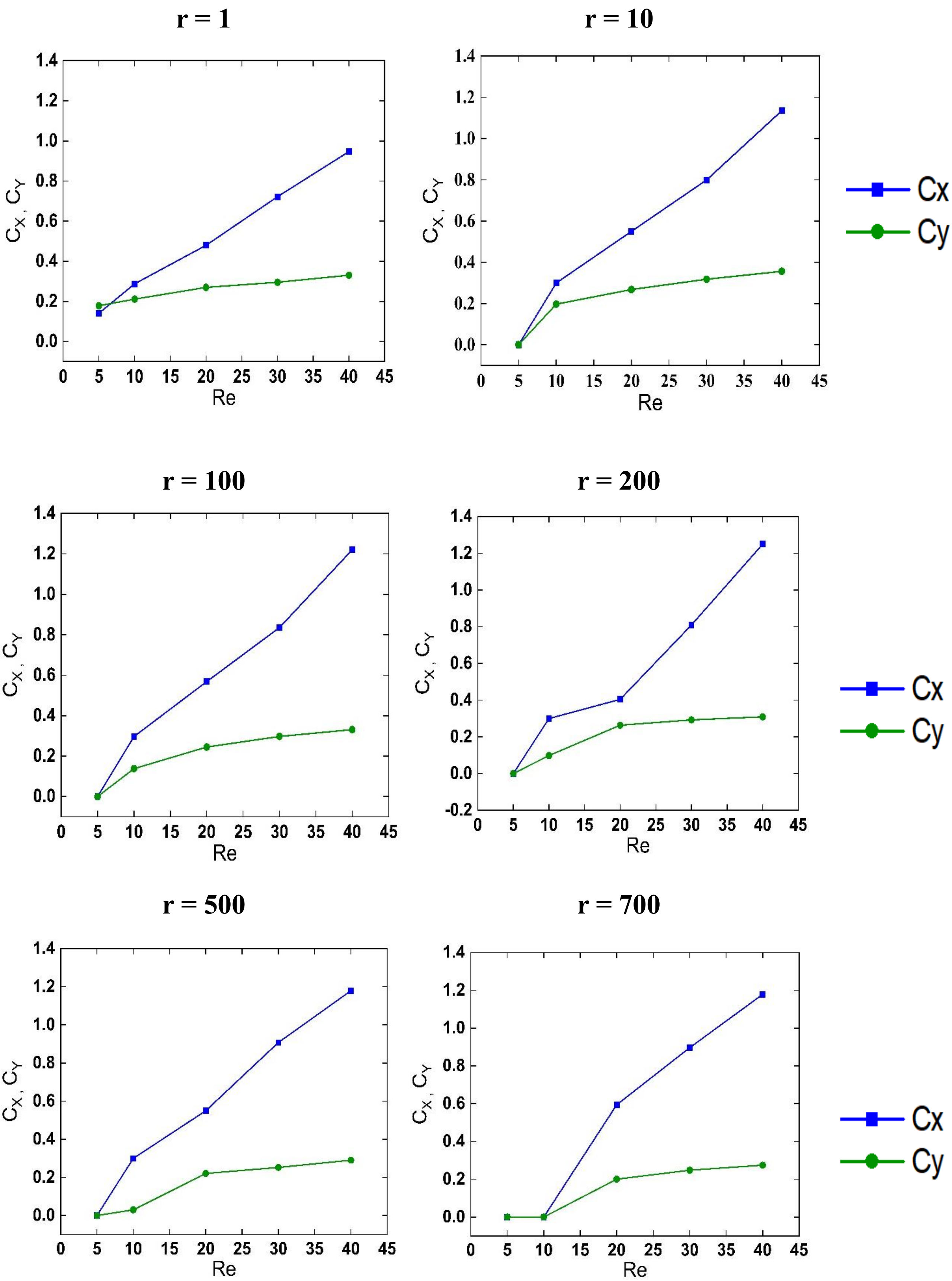


Fig. 4 : Re vs C_X , C_Y for Square geometry for different r value

To compare these C_X and C_Y values for different values of 'r' and their variations with Reynolds Number (Re), these are plotted in OriginLab software and are shown below:

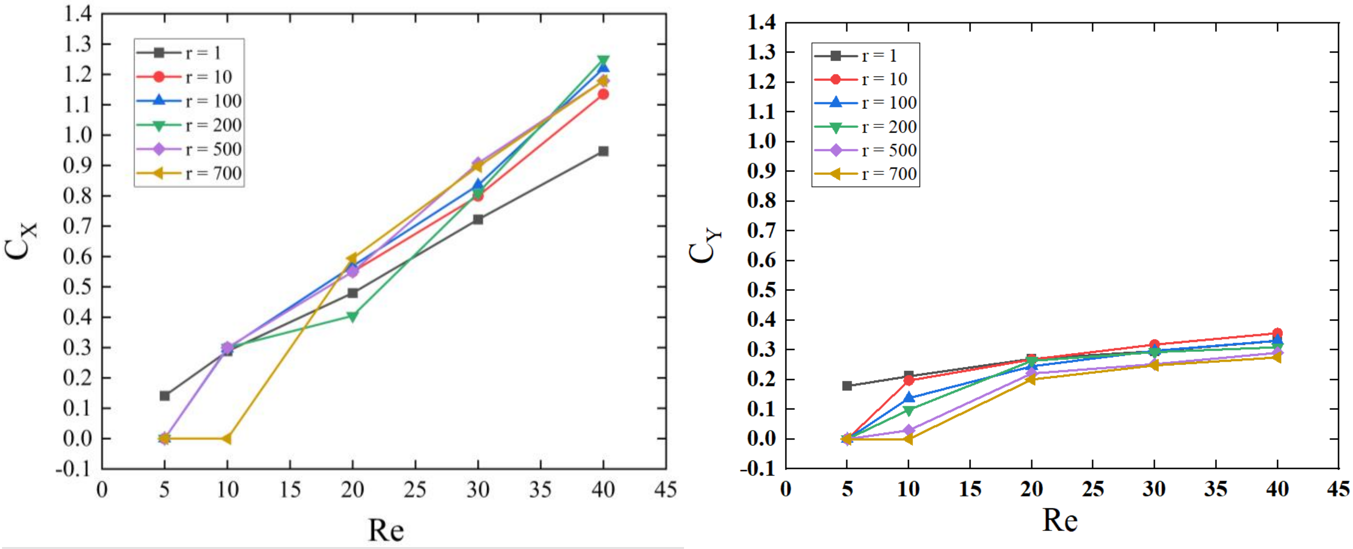


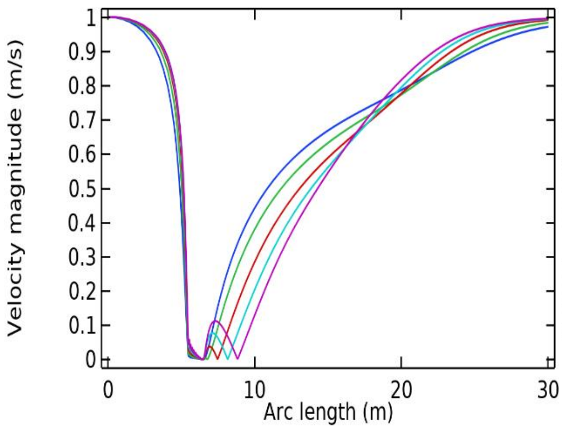
Fig. 5 : Comparison for C_X and C_Y for Square geometry for different r value

From the Fig.5, it is observed as the 'r' value increases i.e., the permeability increases, C_X value increases slightly but the C_Y value decreases slightly. In the Re vs C_X graph it is seen that for high permeable flow (r = 500, 700) at low Reynolds Number (Re = 5 or 10) value of C_X and C_Y are zero which means that there is no recirculating wake region developed at the rear of the geometry. It happens because due to high permeability there is not enough restriction to the flow so no wake formation is there. It is also observed that the value of C_X is significantly higher than value of C_Y which means the length of recirculating wake region is higher than its width.

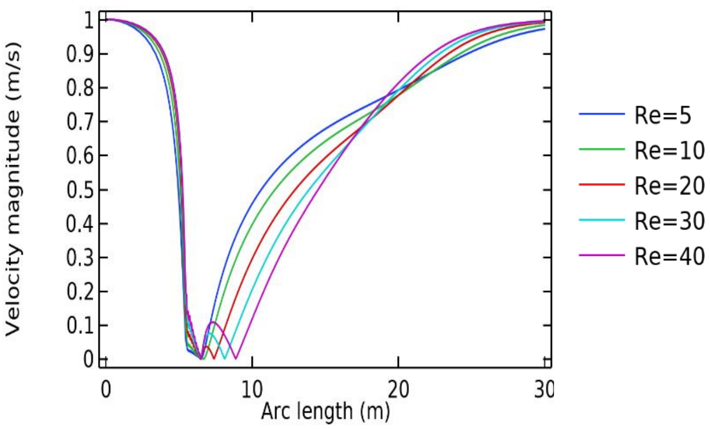
II. Circular Geometry

The following figures show the velocity distribution along the length of the computational domain through the center of geometry for different Re values (Re = 5, 10, 20, 30, 40) and different 'r' values (r = 1, 10 100, 200, 500, 700) :

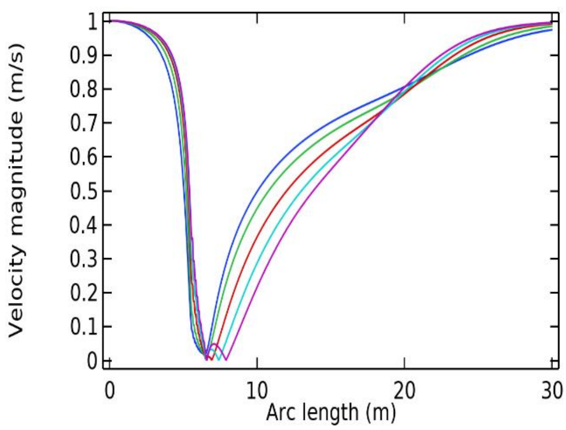
r = 1



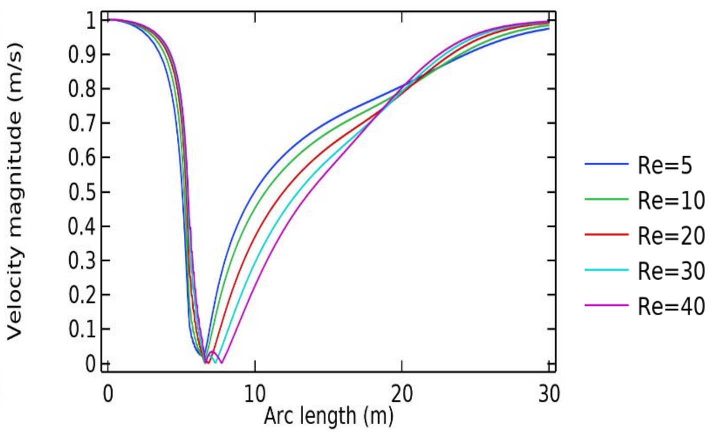
r = 10



r = 100



r = 200



r = 500 **r = 700**

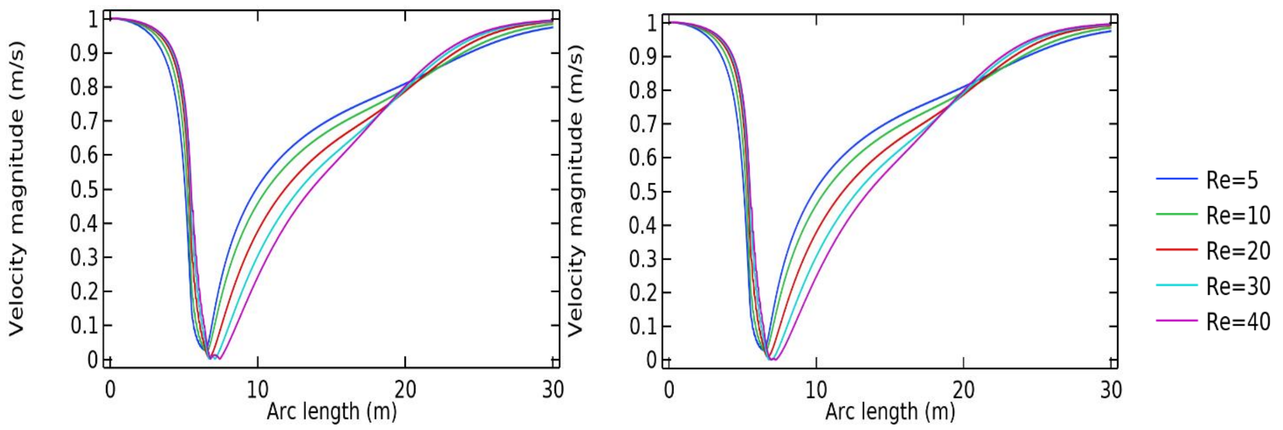
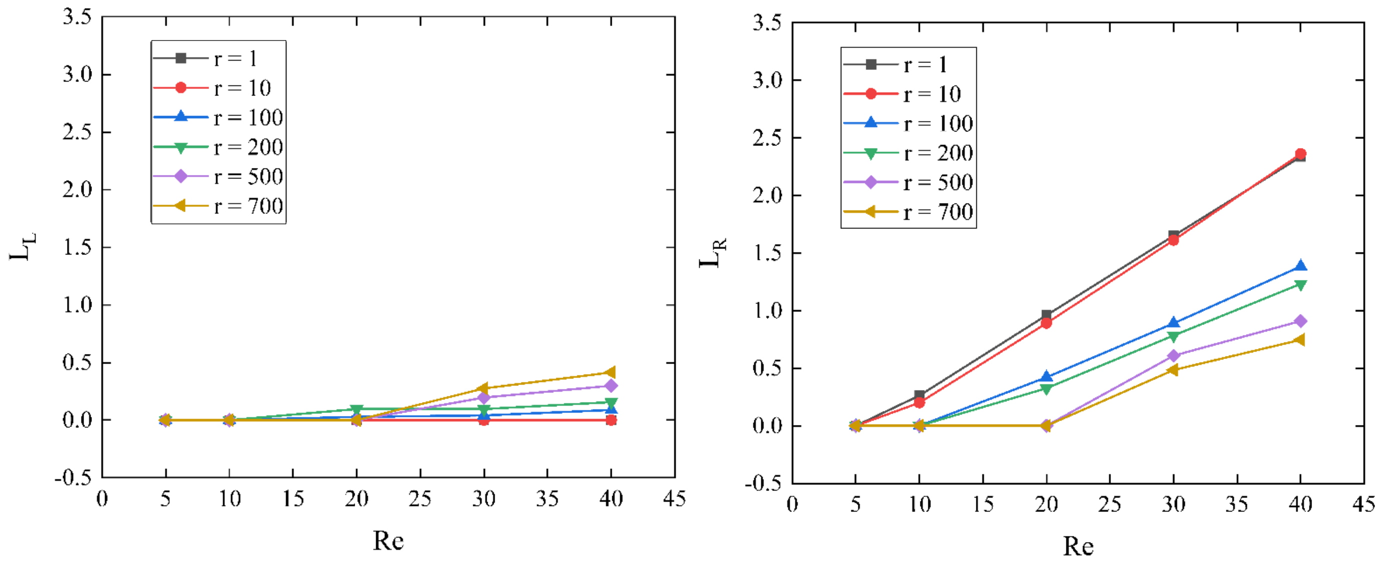


Fig. 6 : Velocity Distribution along the length of domain

From the above velocity diagrams the value of L_L and L_R can be calculated by identifying two stagnation points for a particular Re value and the length of the wake zone L_W can be calculated. Thus, different values of L_L, L_R, L_W are obtained for different Re and 'r' values. These values are plotted in OriginLab software and are shown below:



(a) (b)

Fig. 7 : Comparison for Re vs L_L, L_R for Circular geometry for different r value

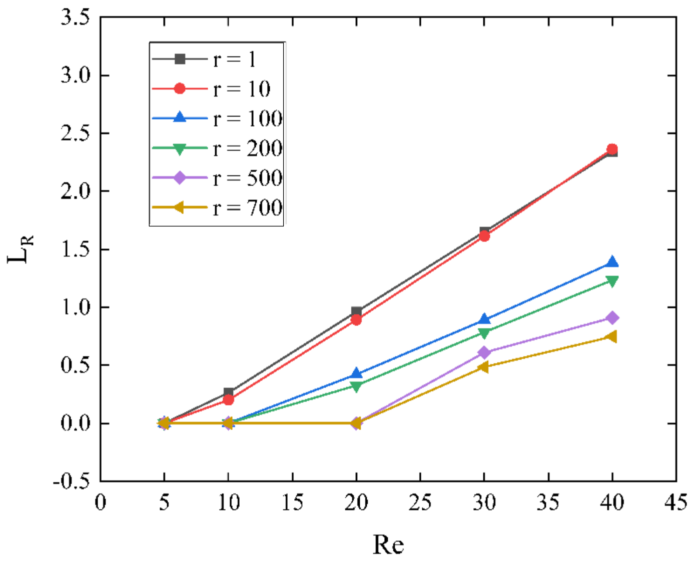


Fig. 8 : Comparison for Re vs L_W for Circular geometry for different r value

From Fig.7(a), it is observed that the L_L value change with Re value and increases slightly with increase in 'r'. For high permeable flow the increase in L_L value is greater than the low permeable flow. It is observed at lower Re value (Re = 5, 10, 20) for high permeable flow i.e., 'r' = 500 or 700, L_L value is zero which necessarily means there is no recirculating wake zone formed for these flows. From Fig.7(b), it is seen the L_R values follow linear trend with Reynolds Number and from r = 10 to r = 700, the L_R values decrease for a particular Re value. It is also seen that for r = 500, 700, the value of L_R at Re = 5, 10, 20 is zero which means no recirculating wake zone formed as stated earlier. Similarly, from Fig.8 it is seen the L_W values follow linear trend with Re and from r = 10 to r = 700, the L_R values decrease for a particular Re value.

The next two important geometrical parameters are C_X and C_Y which helps to locate the center of upper vortex. As discussed earlier, these two are also found from velocity distribution at a particular Re and 'r' value from a defined horizontal and vertical cutline. The following figures show the variation of C_X and C_Y with Re value for a particular 'r' value :

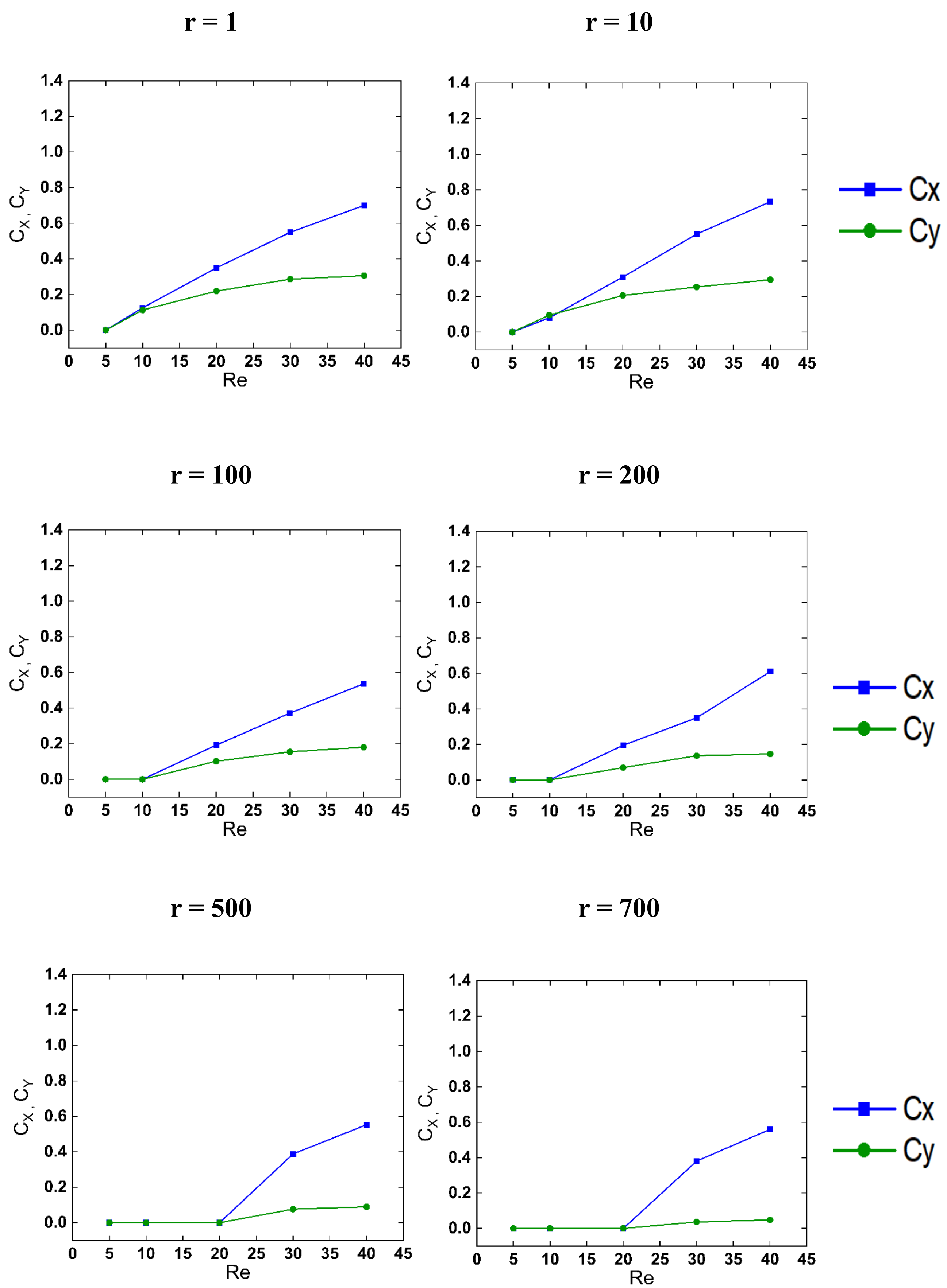


Fig. 9 : Re vs C_X , C_Y for Circular geometry for different r value

To compare these C_X and C_Y values for different values of 'r' and their variations with Reynolds Number (Re), these are plotted in OriginLab software and are shown below:

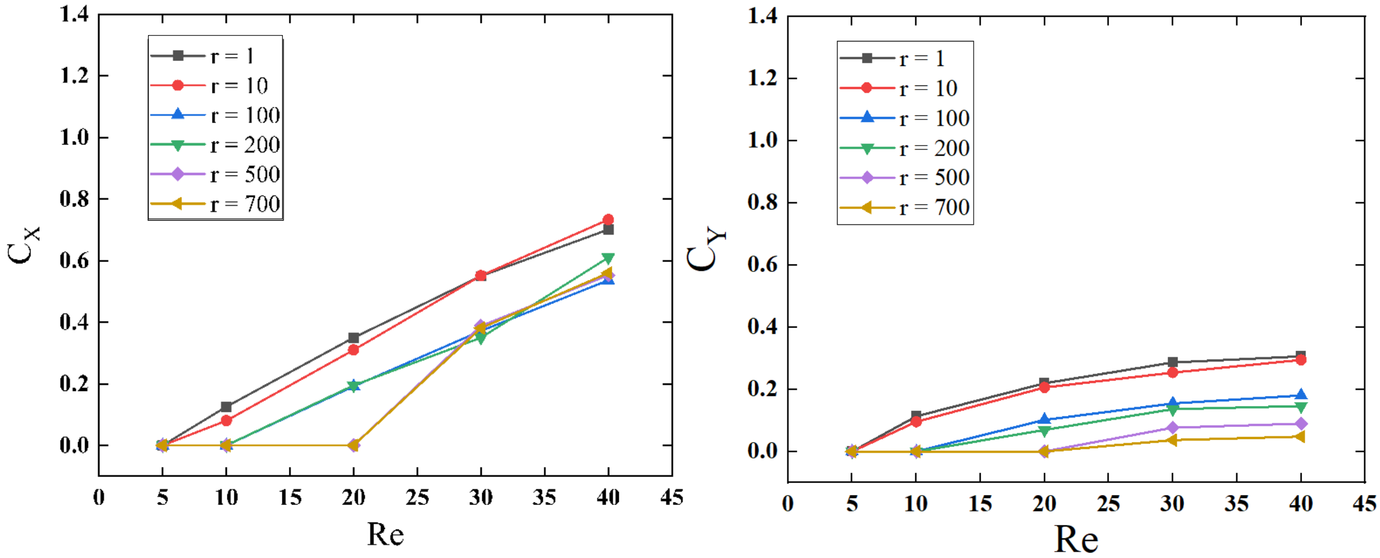


Fig. 10: Comparison for C_X and C_Y for Circular geometry for different r value