Chapter 7

Conclusions and Future Scope

7.1 Conclusions

The SOL plasma is the skin of the main plasma; it protects the main plasma, and can affect the main plasma properties. All the plasma surface interaction takes place in the SOL and this interaction depends on SOL plasma properties. In recent years the existence of the plasma flows in the SOL has been observed and found that the SOL plasma flows can affect the main plasma, which includes the confinement improvement and impurity reduction. The various causes behind these flows are observed and they include Pfirsch-Schluter (PS) flows, $E \times B$ drift, diamagnetic drift, limiter/divertor sink action and the poloidal asymmetry in the particle transport.

In ADITYA, the limiter plasma contact point is only in the limited poloidal region not in the whole poloidal span. That makes the SOL of ADITYA special. In this configuration the outer SOL plasma field lines may be connected to the inner SOL field lines, which is not possible if plasma touches the limiter symmetrically. The effect of this special configuration has been observed in the ADITYA measurements. We have carried out experiments to establish the flow pattern and how it is affected by a small puff of the working gas, and to identify transport and drift driven components of the measured flows. We have used the Mach probes at different toroidal and poloidal locations to measure the flows. ADITYA SOL flow measurements will help to improve and to add to the existing database from other
Chapter 7: Conclusion and Future Scope

tokamaks.

In chapter 4, we have presented the SOL flow along with the other properties in the low toroidal magnetic field $B_T = 0.2$ T and low plasma current $I_p \sim 25$ kA. The directions of both $I_p$ and $B_T$ are in the clockwise (C.W), as seen from the top of the torus. The measured floating potential ($V_f$) at the top of the plasma shows the negative values, which is consistent with the $B \times \nabla B$ direction. The limited contact of the limiter with plasma column gives both short and long connection length $L_{\parallel}$ in the SOL. Its effect has been observed in the density decay length at the top port and the radial port. We have also observed the dependence of toroidal Mach number ($M$) on the radial distance from the last closed flux surface (LCFS) and local plasma density. Our observations confirm reports from other tokamaks. For example, we observe that $M$ increase with the radial distance from the LCFS and the decrease of the $M$ with the increase in the average local plasma density is similar to observation from other tokamaks. Decrease in the $M$ at the higher densities indicates the possible role of the radial electric field in the ADITYA SOL. The $E \times B$ drift and the PS flows of ions are observed to have significant contributions to the measured $M$ and the sink action of the limiter opposes the two. On the other hand, the contribution of the ballooning type transport at the outboard midplane is negligible. The measured toroidal flow direction is towards the ion side of the limiter and the poloidal flow direction is towards the contact of the LCFS with the limiter.

Sometimes the measured plasma flows can be explained by the simple drift and transport driven flows. In some tokamaks the interplay between the mean plasma flows and the turbulence has been observed, and have been used to explain the measured flows. In ADITYA we have carried out measurements to look for the similar effects along with the effect of the gas puff (GP) on the SOL flows and other parameters. In chapter 5, we have reported these measurements in high $B_T = 0.75$ T and high $I_p \sim 80$ kA. Different measured quantities are: plasma density, electron temperature, $V_f$, $M$, fluctuation induced particle flux and Reynolds stress near transition between the long and short $L_{\parallel}$ SOL regions during and before or without GP. The plasma position measurements show that for this counter combination of $B_T$ counter clockwise (C.C.W) and $I_p$ (C.W) the plasma centroid
remains in the first quadrant. At the top port plasma density is nearly flat in the transition region indicating the role of long $L_\parallel$. Measured electron temperature at the top of the plasma in the SOL region reduces to nearly half during the GP and it recovers to the original value in 2-4 ms after the GP. The poloidal flow velocity $V_\theta = E \times B$ reduces nearly to zero during this period. On the other hand, the fluctuation in ion saturation current remains nearly same and the fluctuation in floating potential shows significant reduction.

The shear in the poloidal flow velocity and M is observed near the transition of long to short $L_\parallel$ region. The fluctuation driven particle flux peaks when the parallel Mach number is near zero, and it shows the role of parallel flows in reducing the radial particle flux. Similarly, the particle flux decreases with increasing shear in the M. We have further observed that the turbulence acts as a source and as a sink for both parallel and poloidal momentum in the long to short $L_\parallel$ transition region. However both are decoupled into the far SOL. On the other hand, the turbulence and mean flow are decoupled everywhere during the GP.

The SOL flow pattern is constructed by measuring Mach numbers at three different toroidal and poloidal locations, and it is observed that the parallel flow is towards the ion side in the limiter shadow ($L_\parallel$) but it is towards the electron side in the long $L_\parallel$ region of the SOL plasma at the top port. It is likely that the flow structure forms a convective shell in the SOL region because of special SOL configuration in ADITYA tokamak. The flow direction is towards the electron side of the limiter at all three locations in the presence of GP near the limiter edge. Thus there is a flow reversal at the outboard midplane in the limiter shadow. This phenomenon can be attributed to the location of the GP valve and the source of local ionization of the gas. The measured M has contributions from the ballooning type transport, PS flows, $E \times B$ drift and limiter sink action.

Our measurements presented in chapter 4 and 5 indicate that ADITYA has two types of flow components: drift driven and transport driven. The transport driven and drift driven components are independent and dependent respectively on the $B_T$ and $I_p$ directions. The observed differences in the M presented in chapter 4 and 5 may be because of the different magnitude of $B_T$ and $I_p$ and different direction.
Chapter 7: Conclusion and Future Scope

combinations of $B_T$ and $I_p$.

In chapter 6, we have presented measurements of $M_1$ carried out at the top of the plasma and at the outboard side (away from the midplane), for all four direction combinations of $B_T$ and $I_p$, in order to separate the drift driven Mach number $M_{dr}$ and the transport driven Mach number $M_{tr}$.

Measurements are divided according to positive and negative helicities of the total magnetic field. Both positive and negative helicities consist of two direction combinations. The $B_T$ and $I_p$ are in same direction for the positive helicity case, in different direction for negative helicity case. The estimations are carried out by using: $M_{1,2} = M_{tr} \pm M_{dr}$, where $\pm$ is for the two direction combination of the same helicity. The plasma centroid position is in the first and fourth quadrant for negative and positive helicity cases respectively. The flow has been measured at top of the plasma and at the outboard side above the midplane. We have observed that for the both cases, there is a change in the magnitude and direction of plasma flows. The change in both the magnitude and the direction of flows indicates the presence of both transport and drift driven components. The $E \times B$ and PS flows are observed to be the main factors behind the drift driven component. The transport driven component include the sink action of the limiter and the ballooning transport driven flows. The existence of ballooning transport is seen by the direct measurement of particle flux and density at the outboard and the top port in ADITYA. The dependence of the $M_{tr}$ on the helicity has been observed.

Our measurements have shown the existence of finite transport driven flows in the edge plasma of the ADITYA tokamak. We have also shown that the existence of large flows in the SOL plasma determine reduced outward flux, and hence increased particle confinement. These results will provide database for further modelling of plasma parameters in the ADITYA tokamak.
Chapter 7: Conclusion and Future Scope

7.2 Future Scope

The flows of the order of $M \sim 1$ has been reported in different tokamaks at the inboard side. In ADITYA, inboard side flow measurement may be of great help in identifying the contribution of ballooning type transport in the transport driven flows. The effect of the ballooning type transport driven flows is less on the outboard side as compare to the inboard side, so attempt should be made to measure the $M$ simultaneously at both inboard and outboard side.

In this thesis we have presented the GP effect experiments only for the one direction combination of $B_T$ and $I_p$. The GP experiment should be carried out in both positive and negative helicities, which helps in understanding the effects of different plasma limiter contact location. The location of particle source is known to play a crucial role in the SOL plasma flows; so the experiments should be carried out by varying the GP toroidal/poloidal locations. It helps to understand the effect of particle source location on SOL flows. The duration of GP should be increase to see its extended effects.

The poloidal flows are significant in the tokamak SOL. Our measured floating potential profile shows large gradient, which indicates significant poloidal flows in ADITYA. So attempts should be made to directly measure the direction and magnitude of poloidal flows along with the parallel flows. The direct measurements of poloidal flows will be of great help in determining the parallel/perpendicular flow dynamics in reducing the particle flux, and for the understanding of the turbulence and mean flow coupling. This can be done by using Gundestrup probe.