Transverse drift velocity of a pulsed-plasma in a curved magnetic field

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Abstract. Recent experimental evidence suggests the importance of fast radial plasma transport in the scrape-off-layer (SOL) of tokamaks. The outward transport appears to be convective rather than diffusive, extends into the far SOL, and can produce significant recycling from the main-chamber walls, partially bypassing the divertor. A plausible theoretical mechanism to explain this phenomenon is the radial transport of blobs of locally dense plasma created by turbulent processes. In our experiment, a blob of plasma is produced using a plasma-gun and injected transverse to a non-uniform curved magnetic field inside a curved vacuum chamber. The plasma-blob from the washer stacked plasma gun interacts with the curved magnetic field, which has been created by a pair of coils. The coil is being energized by a capacitor bank. In this paper we report the radial velocity of the plasma-blob in presence of magnetic field. The radial velocity of plasma-blob decreases in the presence of magnetic field in comparison with the velocity without magnetic field.

1. Introduction
One of the possible mechanisms of fast convective plasma transport in the SOL can be associated with plasma blobs\textsuperscript{[1]} observed in many experiments. Transport by blobs provides a robust mechanism for explaining the observed intermittency and radial convection in turbulent SOL plasma.\textsuperscript{[2]} the observed transport is outward for concentration of excess density (blobs) and inward for region of reduced density (holes) \textsuperscript{[3]}. Typical radial velocity is of the order of $10^3$ ms\textsuperscript{-1} \textsuperscript{[4,5]}. One of the chief reasons for recent progress in advanced magnetic confinement configuration has been the experimental mapping of magnetic field lines, from straightforward probing methods to sophisticated imaging technique.

In the present paper we compared the radial drift velocity of plasma blob in presence of magnetic field and in absence of magnetic field. First, the magnetic field generated inside the chamber was measured using a magnetic pick up coil. A blob of plasma was injected into the vacuum chamber using a washer stacked plasma gun, which interacts with two parallel Langmuir probes. The radial drift velocity of plasma blob was measured with and without magnetic field using time of flight technique.
2. Experimental set up
This work is carried out in a curved vacuum chamber made of SS-304 material of length 0.5 m bent into an arc having major radius 40 cm and minor radius 20 cm. The vacuum chamber is highly evacuated by means of a diffusion pump backed by a rotary pump and a pressure of ~ 0.03 mb is maintained throughout the experiment. A pair of insulated copper wire of thickness 2.94 × 10⁻³ m wound over the chamber, each having 25 turns. A pulsed current is generated by a 100μF, 10 kV capacitor bank and a pulsed toroidal magnetic field is generated inside the vacuum chamber. The plasma is injected simultaneously by triggering a washer stacked plasma gun using a multistage pulse-forming network (PFN) consisting of capacitors (~5μF) and inductors (~1μH). The magnetic field generated inside the chamber is measured by using a magnetic probe of 720 turns. The probe is calibrated using Helmholtz Coils. The V ~ t curve from the probe is recorded by an oscilloscope and the magnetic field is calculated by using the relation B(t) = 1/nA ∫ V(t) dt, where n and A are number of turns and area of magnetic pick up coil respectively. ∫ V(t) dt is the area under the V(t) ~ t curve. Two parallel Langmuir probes of distance of separation 2.0 ×10⁻² m are inserted into the chamber as shown in ‘figure 1’. The signals are recorded by a four-channel storage oscilloscope connected to a PC. The block diagram of the setup is shown in ‘figure 2’.

![Figure 1.](image-url)
2.1. Radial velocity measurement

The radial drift velocity $v$ of the blob is measured by using two parallel transverse probes kept at a known distance from the plasma gun inside the chamber. The radial velocity of the blob of plasma is measured with and without magnetic field by time of flight technique using the following equation.
\[ v = \frac{\Delta d}{\Delta t} \]  \hspace{1cm} (2)

Where, \((\Delta t)\) is the time elapsed to travel distance \((\Delta d)\) between two probes.

\[ \text{Figure 4. Radial velocity profile of the plasma blob.} \]

3. Results and discussion
To start with we have applied a magnetic field of \(~400\text{G}\). In the present case we have measured the magnetic field at the extreme end of the chamber by a magnetic pick up coil as shown in ‘figure 3’. The field is around 40G. However, at the central region of the chamber the magnetic field is around 400G which matches well with the theoretical prediction. The radial drift velocity of plasma blob is measured using ‘equation (2)’. The variation of velocity with distance by moving the probes radially from the plasma gun is plotted in ‘figure 4’, with and without magnetic field. As expected, the velocity without magnetic field \((\sim 10^3 \text{ms}^{-1})\) decreases with distance from plasma gun as in [6]. The velocity with magnetic field is also of the order of \(10^3 \text{ms}^{-1}\) but is less than that of without magnetic field. The velocity with \(B = 400 \text{G}\) varies from \(3.3 \times 10^3 \text{ms}^{-1}\) to \(7.1 \times 10^2 \text{ms}^{-1}\) when the radial distance from the plasma gun increases. As the plasma gun is placed at the high field side of the chamber, where the magnetic field is higher than its value at the center \((\sim 400 \text{G})\), we observed more variation (decrease) in the velocity. Further away from the gun, where the magnetic field decreases as \(1 / R\), the velocity does not vary much. This observation suggests that we need higher magnetic fields to bring a substantial change in the plasma velocity compared to without magnetic field.
4. Conclusions
The transverse drift velocity of a pulsed plasma in a curved chamber is measured by time of flight method as a function of distance from the plasma gun where the plasma is produced. In absence of the magnetic field, the velocity decreases from ~ 4 km/sec to ~ 0.5 km/sec as the distance form the gun is increased. In presence of magnetic field of ~ 400 Gauss at the vessel center the velocity profile (as a function of distance from the gun) remains the same, however, the magnitude of the velocity decreases in comparison to the without magnetic field case.

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