BMC JOURNAL OF SCIENTIFIC RESEARCH
A Multidisciplinary Peer Reviewed Research Journal
ISSN: 2594-3421 (Print), 2773-8191 (Online)

Study of Fitted and Computed Plots in Magnetized Plasma Sheath

B. R. Adhikari[1]* and R. Khanal[2]
[1]Department of Physics, Bhaktapur Multiple Campus, Bhaktapur
[2]Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal
*Corresponding Author: b.r.adhikari@hotmail.com
Received: June 13, 2022, Accepted: Nov. 30, 2022

Abstract
Velocity profile of ions at the sheath entrance position with various obliqueness of the magnetic field has been studied. The oscillation amplitude of the velocity decreases as time increases. The mean values of different component of velocity also changes. The computed and fitted values of the vector sum of oscillatory part of x, y and z-component of velocities of the ions are nearly matches. At angle 30°, damping rate of vector sum of oscillatory part of total velocity increases from 1 to 5 mT. On the other hand vector sum of oscillating part of initial velocity is almost equal for magnetic field 1 mT, 3 mT and 5 mT at the same angle.
Keywords Plasma sheath; Damping constant; Frequency of oscillation; Bohm criterion.

1. Introduction
The study of velocity profile of ions by applying magnetic field in a plasma sheath with varying obliqueness as well as variation of vector sum of oscillating part of total velocity with time is significant and current field of research but yet is not totally solved. The magnetic field introduced in the plasma sheath makes the problem vast but yet exciting. The work associated to experiment and theory have been improved all these years[1, 2]. Our ongoing work in this paper is unique and totally new than any other. Currently, the sheath formed between magnetic plasma and the wall which absorbs the electron has received a massive attention [3-7]. As plasma is bound to the closed vessel, obviously interaction of plasma takes place with the walls and such interaction may be desired (e.g. surface treatment) or undesired (e.g. in fusion devices)[12]. The obstacle with the formation of sheath is very important in which the plasma contact with the absorbing wall.

There are various methods that significantly focus on the study of sheath and presheath in the magnetic field. According to Chodura [1] as the magnetic field is applied making certain angle with the surface of solid , magnetic presheath appears, that liberates certain electric field around this area and developed the model of theory to generate sheath, viz., criteria of Bohm-Chodura plasma sheath. Chodura explained that in the existence of the inclined magnetic field, the potential distribution consists of two distinct scaled structures. One is Debye sheath and next is Chodura sheath [9,10]. Chodura brought a new situation to the ion velocity that enters the presheath satisfying the criteria called Bohm condition [2]. Because of higher velocity of electrons as compared to that of ions,

the negative potential is developed in the absorbing wall. Due to negative potential of wall, moving electrons are repelled back, as a result there is formation of positive space charge region which we say sheath. Plasma wall transition is the area between the bulk plasma and the solid surface. The bulk plasma behavior is affected by the magnetized plasma sheath. The plasma sheath feature is delicate function of the direction of ambient magnetic field compared to the wall [12,13]. The sheath layer size as well as the angle between the wall and field magnetization is inversely related to each other [8]. Equation of the fitted curve is used which is almost matching with the computed plot.
The management of our work is as below: In second section we have discussed the principle of Kinetic Trajectory Simulation (KTS) model. In the collision less case this section describes the distribution function. In section three we discuss the model of plasma sheath in the presence of magnetic field. We explained the result and discussion in section four in which we apply Lorentz force equation in MATLAB and boundary condition is used.

2. Methods and Model

Figure 1 shows the boundation of plasma by two parallel planes at $x = 0$ and $x = L$. The simulation region, $x = 0$ is designed as the sheath entrance and $x = L$ is the perfectly non-emitting material wall [14].

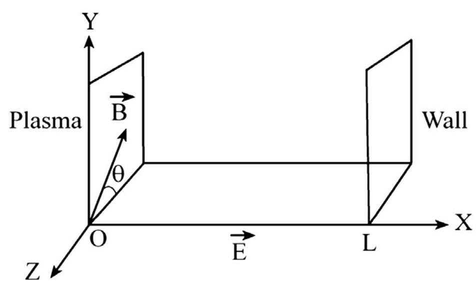

Fig. 1: Schematic diagram of the plasma sheath model

The various components of velocity of ions having different components is written as [7]

$$m\frac{d\vec{v}}{d\,t} = q(\vec{v}\times\vec{B}) + q\vec{E} \tag{1}$$

Where q, m and v denotes the charge, mass and velocity of ion. B as well as E noted the magnetic and electric field

We use equation of the fitted curve as [7,11]

$$v = v_0 e^{-t/\tau} \tag{2}$$

Where v_0 is the initial value of v in m/s and τ is the characteristic time which is written as

$$\tau = t_1 + \frac{v_1 - v}{v_1 - v_2}\Delta t \tag{3}$$

Where v_1 and v_2 represents the resultant velocity at time t_1 and t_2, whereas Δt is the interval of time.

3. Results and Discussion

As in figure 2, at magnetic field 1 mT and angle 30°, the velocity of the ions at the sheath entrance is observed at different time interval . Frequency of oscillation of each component is almost equal ie 55.5 Hz . The oscillation amplitude of the velocity decreases as time increases and the mean value of each component of the velocity were obtained as -11.5, 6523 and 11690 ms^{-1} respectively. As we computed the resultant of oscillatory part of all three component of the velocity, we found an exponential damping of the velocity as shown in figure 3. The fitted curve in figure 3 is almost matching with the computed plot. The equation of the fitted curve is $v = v_0 e^{-t/\tau}$ $=10.456\times10^3 e^{-t/0.414}$, where v_0 is the initial value of v and τ is the characteristic time

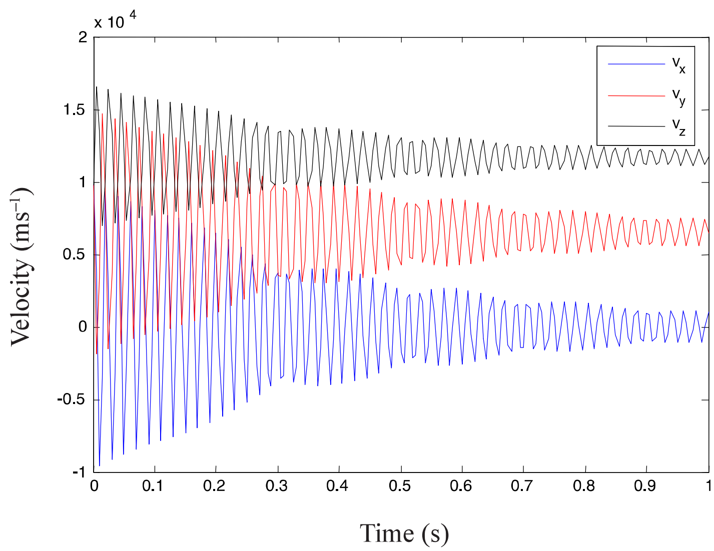

Fig. 2: Velocity and time variation at magnetic field 1 mT and angle 30°

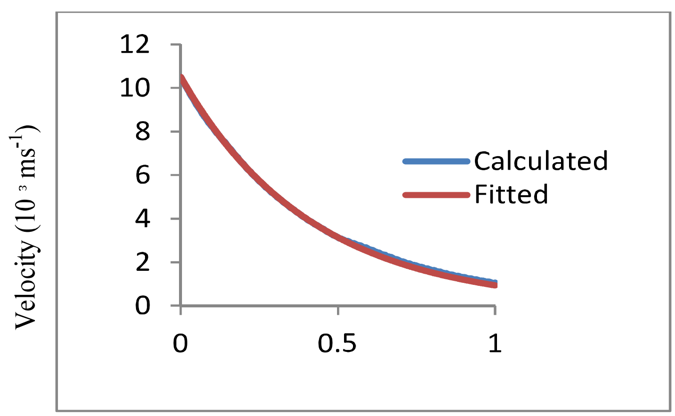

Fig. 3: Oscillatory part of total velocity with respect to time at magnetic field 1 mT and angle 30°

At magnetic field 3 mT and angle 30°, the velocity of the ions at the sheath entrance is observed at various time as shown in figure 4. Frequency of oscillation of each component is equal to 52.2 Hz. The oscillation amplitude of the velocity decreases as time increases and the mean value of each component of the velocity were obtained as 2.5, 6620 and 11630 ms^{-1} respectively. Like previous as we computed the resultant of oscillatory part of all three component of the velocity, we found an exponential damping of the velocity as shown in figure 5. The fitted curve in figure is almost matching with the computed plot. The equation of the fitted curve is $v = v_0 e^{-t/\tau} = 10.41\times10^3 e^{-t/0.138}$, where v_0 is the initial value of v and τ is the characteristic time.

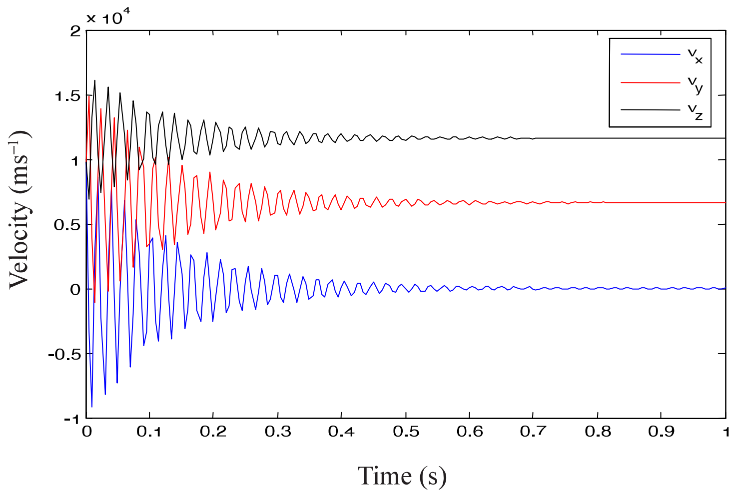

Fig. 4: Temporal variation at magnetic field 3 mT and angle 30°

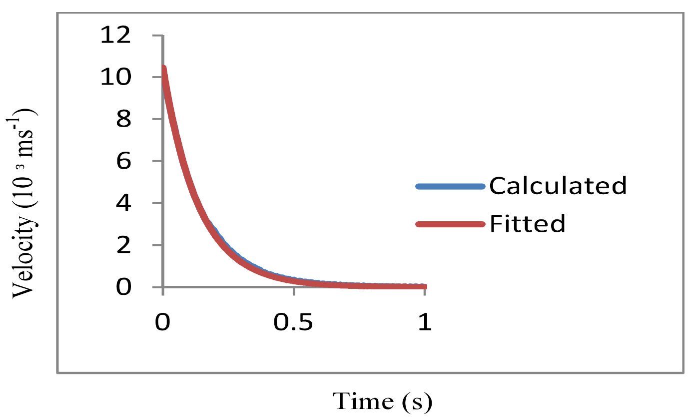

Fig. 5: Oscillatory part of total velocity with respect to time at magnetic field 3 mT and angle 30°

At magnetic field 5 mT and angle 30°, the velocity of the ions at the sheath entrance is observed at various time as shown in figure 6. Frequency of oscillation of each component is equal to 58.8 Hz. The oscillation amplitude of the velocity decreases as time increases and the mean value of each component of the velocity were obtained as 0.0548, 6655 and 11610 ms^{-1} respectively. Like previous as we computed the resultant of oscillatory part of all three component of the velocity, we found an exponential damping of the velocity as shown in fig 7. The fitted curve figure 7 is almost matching with the computed plot. The equation of the fitted curve is $v = v_0 e^{-t/\tau} = 13.802\times10^3 e^{-t/0.083}$,where v_0 is the initial value of v and τ is the characteristic time.

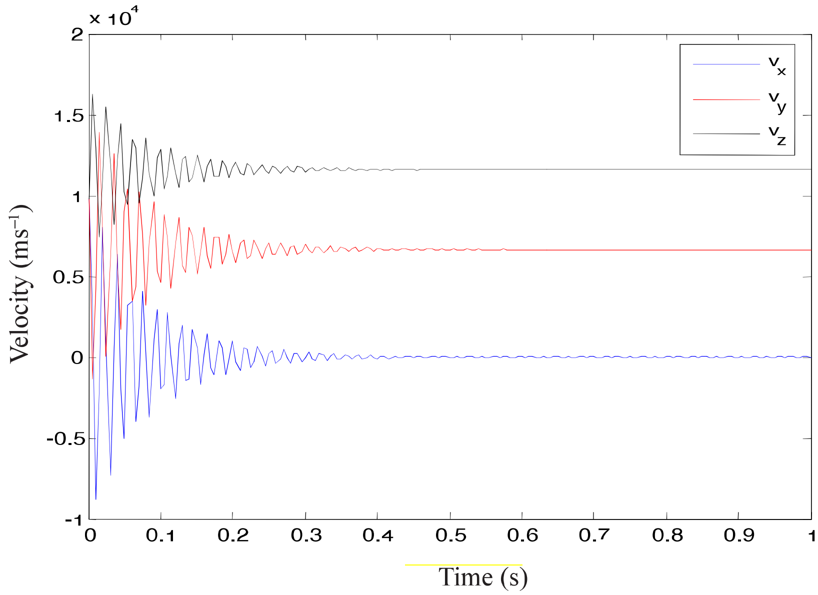

Fig. 6: Variation of velocity with time at magnetic field 5 mT and angle θ = 30°

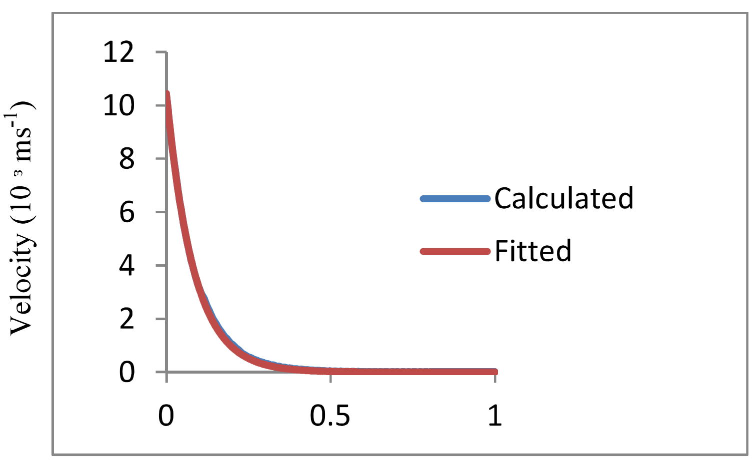

Fig. 7: Oscillatory part of total velocity with respect to time at magnetic field 5 mT and angle 30°

Similarly, figure 8 shows the temporal variation of total velocity at angle 30° and different magnetic field (1 mT, 3 mT and 5mT). This figure shows that at obliqueness 30° initial velocity of the ions is almost same at different magnetic field. Likewise the damping rate of vector sum of oscillatory part of total velocity increases from magnetic field 1 mT to 5 mT at obliqueness 30°.

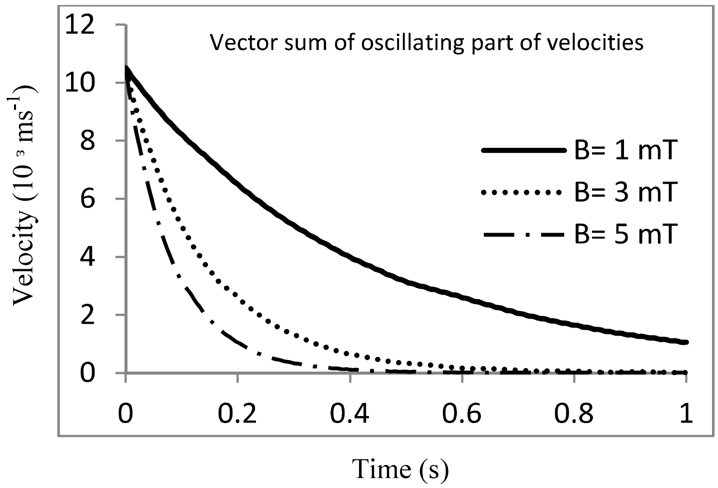

Fig. 8: Variation of vector sum of oscillating part of total velocity with respect to time at angle 30° and different magnetic field.

4. Conclusion

The oscillation amplitude of the velocity decreases with the increase in time. The mean values of different component of velocity also changes. It has been concluded that the fitted curve is almost matching with the computed plot. Also, damping rate of vector sum of oscillatory part of total velocity increases from 1 to 5 mT. Finally it has been concluded that, vector sum of oscillating part of initial velocity is almost equal for different magnetic field. The obtained results were qualitatively similar with previous literature,[7,13] and quantitatively it is different.

References

1. Chodura, R. 1982. Plasma wall transition in an oblique magnetic field. *Phys. Fluids*. **25**: 1628.
2. Riemann, K. U. 2000. Theory of the plasma sheath-transition. *J. Tech. Phys*. **41**: 89.
3. Khanal, R. 2002. A Kinetic Trajectory Simulation (KTS) Model for Bounded Plasma, Ph. D. Thesis, Innsbruck University, Austria.
4. Hatami, M. M., Niknam, A. R., Shokri, B. and Ghomi, H. 2008. Magnetized plasma sheath with two species of positive ions. *Physics of Plasmas* **15**: 053058 1.
5. Chen, F. F. 2016. Introduction to plasma physics and controlled nuclear fusion (3rd ed.), Springer, Switzerland.

6. Adhikari, B. R., Basnet, S., Lamichhane, H. P. and Khanal, R. 2018. Beat frequency and velocity variation of ions in a magnetized plasma sheath for different obliqueness of the magnetic field. *Journal of Institute of Science and Technology*. **23**: 88.
7. Adhikari, B. R. & Khanal, R. 2021. Temporal ion velocity variation with obliqueness in magnetized plasma sheath . *Journal of Nepal Physical Society*. 7: 138.
8. Chalise, R. & Khanal, R. 2015. Self-consistent one dimension in space and three dimension in velocity kinetic trajectory simulation model of magnetized plasma-wall transition. *Physics of Plasmas*. **22:** 113505 1.
9. Hatami, M. M. 2018. Sheath properties in two-temperature Non-Maxwellian electron plasmas. *IEEE Transactions on Plasma Scienc*e. **46**: 868.
10. Moulik, R. & Goswami, K. S. 2015. Potential around a dust grain in collisional plasma. *Physics of Plasmas*. **22**: 043701.
11. Hatami, M. M.; Niknam, A. R.; Shokri, B. & Ghomi, H. 2008. Magnetized plasma sheath with two species of positive ions. *Physics of Plasmas* **15**: 053058 1.
12. Chalise, R. and Khanal, R. 2012. A kinetic trajectory simulation model for magnetized plasma sheath. *Plasma Phys. Control. Fusion*. **54**: 095006-5.
13. Adhikari, B. R.; Basnet, S.; Lamichhane, H. P. and Khanal, R. 2019. Presheath-sheath coupling for kinetic trajectory simulation of a magnetized plasma sheath. *AIP Advances.* **9**, 055123-10.
14. Adhikari, B. R., Lamichhane, H. P. and Khanal, R. 2020. Variation of mean value of velocity of ion with different obliqueness of magnetized plasma sheath. *Him. Phys*. **9**: 53