CHAPTER - III

_neurons_ 

Force on a Positive Ion
CHAPTER III
FORCE ON A POSITIVE ION

3.1 INTRODUCTION

The magnetoelectrostatic trap formed by the cusped magnetic field with electrostatic end plugging taken for study is shown in Fig. 1.3(a)[Chapter I] [1]. Inside this trap, a positive ion experiences a decelerating force due to the electric and magnetic fields [2] given by:

\[ F_z = q(E_z - v_\theta B_r) \] ...

(3.1)

where \( v_\theta \) is the azimuthal component of velocity. The other two components of the force on the particle in this combined field are not significant for the present discussion.

Confinement of the particle inside the trap depends mainly on the decelerating force on the particle. The decelerating force \( F_z \) consists of a centrifugal component \( (F_c) \) and a mirror component \( (F_m) \). In a cusped magnetic field, the ring cusp rather than the axial apertures are the primary channels for escape of the particle from the electromagnetic confinement system [3]. Hence additional forces should operate near the axial apertures to oppose the free escape of charged particles along the flux tube. These forces may result from a component of the electrostatic confinement system.

If the displacement of a particle during a Larmor period is small in comparison with the distances over which there are substantial changes in the electric and magnetic fields, then the motion of the particle can be described by the drift theory [4,5].
In this case the particle moves near an axisymmetric magnetic surface which is also a surface of constant electrostatic potential. Since \( r = r_L \), the average acceleration of the particle along the direction of the magnetic field is

\[
\left( \frac{dv_{\parallel}}{dt} \right) = \frac{V_e^2 B_r}{r B} - \frac{v_L^2 \partial B}{2B \partial s}
\]

(Eq. 2.24, Chapter II) ...(3.2)

where \( V_e = c[B \nabla \Phi]/B^2 \) is the electric drift velocity, \( v_L \) is the Larmor revolution velocity, \( c \) is the velocity of light in vacuum and \( s \) is the arc length along a magnetic line of force.

The first term on the right side of Eq. (3.2) results from the component parallel to the magnetic field of the centrifugal force caused by the azimuthal drift of the charged particle in the crossed electric and magnetic fields and the second term is the acceleration due to the ordinary mirror repulsion of the particle into a region of weaker magnetic field.

Average force on a nonrelativistic positively charged particle (hydrogen ion) in a system of cylindrically symmetric cusped magnetic field configuration with electrostatic end stopper has been studied extensively and important criticisms have been discussed using a single-gap mathematical model. The parallel component of the averaged decelerating force acting on the particle was computed. The particle was assumed to be injected with its velocity in the positive \( z \)-direction at a point on the downstream side of the cusp plane. The decelerating force was found to depend on the location of the particle injection, injection velocity, its
azimuthal component, magnetic field strength and the electrostatic potential applied to the electrodes. The combined force due to the crossed electric and magnetic fields plays an important role in the particle confinement inside the cusp system. The decelerating force increases with increase in electrostatic potential and decreases with increase in the magnetic field strength.

Previous studies [3] showed that the plasma leakage through the cusp apertures was greatly reduced and the confinement time increased for sufficiently high density plasmas \((n > 10^{16} \text{ m}^{-3})\) by the use of electrostatic field. Dolgopolov et al. [3] reported that the electrostatic field improved the confinement time of an ion in the system and the effect was more significant at axial apertures. The results of \(F_\parallel\) as a function of \(v_{\phi 0}\) for selected values of injection point reported earlier [3] are in good agreement with the present results.

However a detailed study on the force acting on the particle in the electromagnetic system has not been reported yet.

In this chapter, the effect of the strength of magnetic field \((B)\), the negative electrostatic potential \((\Phi_A)\), the location of the injection point of the particle into the cusp system \((z_0)\), initial velocity \((v_0)\) and initial azimuthal component of velocity \((v_{\phi 0})\) on the parallel component of the retarding force \((F_\parallel)\) on the particle are studied. \(v_{\phi 0}\) and \(\Phi_A\) are found to have a strong control over \(F_\parallel\). The cusp field dimensions and intensity of magnetic field used in the present analysis are based on those used in the experiments of Azovkii et al. [6].
The parallel component of the decelerating force on the particle at each point of its trajectory was computed and averaged over a Larmor period \( \tau_L \) (= \( 2\pi/\omega_e \)) which is much greater than the step size used for the integration of the equations of motion.

### 3.2 RESULTS

The results of the effect of the strength of magnetic field \( (B) \), the negative electrostatic potential \( (\Phi_A) \), the location of the injection point of the particle into the cusp system \( (z_0) \), initial velocity \( (v_0) \) and initial azimuthal component of velocity \( (v_{0\theta}) \) on the parallel component of the retarding force \( (F_{||}) \) on the particle[7] are reported and discussed.

#### 3.2.1. Effect of magnetic field \( (B) \)

The results of the average decelerating force \( F_{||} \) as a function of \( B \) for selected values of \( z_0, \Phi_A, v_0, \theta \) and \( \Psi \) are illustrated in Figs. 3.1(a) to 3.1(f). The initial values were fixed as \( z_0 = 5 \text{ cm}, \Phi_A = 600 \text{ V}, v_0 = 1x10^5\text{ms}^{-1}, \theta = 0 \text{ and } \Psi = 0 \). The general pattern of the figures are that \( F_{||} \) initially decreases sharply and then gradually thereafter. The characteristic appears to be asymptotic about the axes. The results indicate that an increase in the magnetic field weakens \( F_{||} \).

In Fig. 3.1(a), \( F_{||} \) as a function of \( B \) for selected values of \( z_0 \) are given. For small values of \( B \), \( B = 0.1 \) to 0.75 T, \( F_{||} \) decreases sharply first and then gradually as \( B \) increases. As the location of the injection point moves away from the mid plane, the \( F_{||} \) decreases considerably. For \( z_0 = 1, 2, 3, 4, \) and 5 cm, the \( F_{||} = 400, 230, 180, 150 \) and 130 V cm\(^{-1}\) respectively at \( B = 0.5 \text{ T} \). It is seen that there is 50% decrement in \( F_{||} \) for \( z_0 \)
FIG. 3.1(a). Parallel component of the decelerating force ($F_\parallel$) as a function of $B$ for selected values of $z_0$ with $v_0 = 1 \times 10^5$ ms$^{-1}$, $v_{\phi 0} = 0$, $\theta = 0$, $\Psi = 0$ and $\Phi_A = 600$ V.
FIG. 3.1(b). Parallel component of the decelerating force \( F_y \) as a function of \( B \) for selected values of negative \( z_0 \) with \( v_0 = 1 \times 10^5 \text{ ms}^{-1} \), \( v_{\phi 0} = 0 \), \( \theta = 0 \), \( \Psi = 0 \) and \( \Phi_A = 600 \text{ V} \).
FIG. 3.1(c). Parallel component of the decelerating force ($F_\parallel$) as a function of $B$ for selected values of $\Phi_A$ with $v_0 = 1 \times 10^5$ m s$^{-1}$, $v_{\phi_0} = 0$, $\theta = 0$, $\Psi = 0$ and $z_0 = 5$ cm.

Magnetic field (B) Tesla

- $\Phi_A = 250$ V
- $\Phi_A = 500$ V
- $\Phi_A = 750$ V
- $\Phi_A = 1000$ V
- $\Phi_A = 1250$ V
FIG. 3.1(d). Parallel component of the decelerating force ($F_\parallel$) as a function of $B$ for selected values of $v_0$ with $\Phi_A = 600$ V, $v_{40} = 0$, $\theta = 0$, $\Psi = 0$ and $z_0 = 5$ cm.
FIG. 3.1(e). Parallel component of the decelerating force ($F_{||}$) as a function of $B$ for selected values of $\theta$ with $\Phi_A = 600$ V, $v_{\phi_0} = 0$, $v_0 = 1 \times 10^5$ ms$^{-1}$, $\Psi' = 0$ and $z_0 = 5$ cm.
FIG.3.1(f). Parallel component of the decelerating force ($F_y$) as a function of $B$ for selected values of $\psi$ with $\Phi_A = 600$ V, $v_{x0} = 0$, $v_0 = 1 \times 10^5$ ms$^{-1}$, $\theta = 0$ and $z_0 = 5$ cm.
increasing from 1cm to 2 cm. But $F_\parallel$ decreases steeply for further increase of $z_0$. When the particle is injected in the pre-cusp plane region, $z_0$ having negative values, $F_\parallel$ exhibits similar nature to that of $z_0$ with positive values (Fig. 3.1(b)).

The results of calculating $F_\parallel$ as a function of $B$ for selected values of $\Phi_A$ are shown in Fig. 3.1(c). The nature of variation is the same as that of Fig. 3.1(a). For $\Phi_A = 250, 500, 750, 1000$ and 1250 V, the corresponding values of $F_\parallel$ are 40, 100, 220, 350 and 550 V cm$^{-1}$ at $B = 0.5$ T. The increase is initially 40% and becomes 63% for change of $\Phi_A = 1000$ to 1250 V. This sharp rise in $F_\parallel$ due to increase in $\Phi_A$ confirms that the applied potential prevents the escape of particle through the axial aperture.

Similar results of $F_\parallel$ as a function of $B$ for selected values of $v_0$ are illustrated in Fig. 3.1(d). Change in $v_0$ does not produce any significant change in $F_\parallel$.

Figs 3.1(e) and 3.1(f) show the effects of $B$ on $F_\parallel$ for selected values of $\theta$ and $\Psi$ respectively. It is seen that there is no considerable change in $F_\parallel$ for different values of $\theta$ and $\Psi$. Hence these parameters were fixed as zero for the entire study of the decelerating force.

3.2.2. Effect of applied electrostatic potential $\Phi_A$.

The results of the study of the effect of $\Phi_A$ on $F_\parallel$ for selected values of $z_0$, $B$ and $v_0$ are illustrated in Figs 3.2(a) to 3.2(c). The general features of effect are that an increase in $\Phi_A$ increases $F_\parallel$. The increase is very gradual till $\Phi_A = 500$ V and thereafter the variation is steep. In Fig. 3.2(a), the results of $F_\parallel$ as a function of $\Phi_A$ for selected values of $z_0$ are illustrated. For $z_0 = 1, 2, 3, 4$ and 5 cm, the corresponding $F_\parallel$ values are
FIG. 3.2(a). Effect of $\Phi_A$ on $F_\parallel$ for selected values of $z_0$ with $v_o = 1 \times 10^5$ ms$^{-1}$, $v_{fo} = 0$ and $B = 2$ T.
FIG. 3.2(b). Effect of $\Phi_A$ on $F_\parallel$ for selected values of $B$ with $v_0 = 1 \times 10^5$ ms$^{-1}$, $v_{\phi 0} = 0$ and $z_0 = 5$ cm.
FIG. 3.2(c). Effect of $\Phi_A$ on $F_\parallel$ for selected values of $v_0$ with $z_0=5$ cm, $\theta_0=0$ and $B=2$ T.
150, 110, 80, 70 and 60 V/cm, showing a fast decrease with increase in \( z_0 \) of \( F_{\parallel} \). Hence it is seen that the injection point plays an important role in particle confinement.

Similar results of \( F_{\parallel} \) as a function of \( \Phi_A \) for selected values of \( B \) are shown in Fig. 3.2(b). At \( \Phi_A = 1000 \text{ V} \), \( F_{\parallel} \) decreases by 60% for increase in \( B \) from 0.5 to 1.0 T.

For selected values of \( v_0 \), the effect of \( \Phi_A \) on \( F_{\parallel} \) is illustrated in Fig. 3.2(c). It is seen that the variation of \( v_0 \) did not show any significant effect on \( F_{\parallel} \). However the marginal increase becomes larger with increase in \( \Phi_A \) and the effect is 16% at \( \Phi_A = 1000 \text{ V} \) for change in \( v_0 \) from 0.5 to 2.0.

### 3.2.3. Effect of location of injection point (\( z_0 \))

Effect of \( F_{\parallel} \) as a function of \( z_0 \) for selected values of \( B \), \( \Phi_A \) and \( v_0 \) are shown in Figs. 3.3(a) to 3.3(c). The general characteristic of the curve is that the \( F_{\parallel} \) decreases as \( z_0 \) increases. In Fig. 3.3(a), the calculated values of \( F_{\parallel} \) as a function of \( z_0 \) for selected values of \( B \) are illustrated. At \( z_0 = 5 \text{ cm} \), \( F_{\parallel} \) decreases with increase of \( B \); for \( B = 0.5 \text{ T} \) the corresponding \( F_{\parallel} = 155 \text{ V cm}^{-1} \) and for \( B = 1.0 \text{ T} \), the \( F_{\parallel} = 55 \text{ V cm}^{-1} \); the decrease is 64.6%. For further increase in \( B \), \( F_{\parallel} \) decreases gradually first and then appears to tend a constant value. It is seen that if the particle is injected nearer to the cusp ends, it is prone to escape through the flux lines.

The results of \( F_{\parallel} \) as a function of \( z_0 \) for selected values of \( \Phi_A \) are illustrated in Fig. 3.3(b). For a given \( z_0 \), \( F_{\parallel} \) is larger as \( \Phi_A \) is larger; \( F_{\parallel} \) is 5, 25, 50 and 75 V cm\(^{-1}\) for \( \Phi_A = 250, 500, 750 \) and 1000 V respectively at \( z_0 = 3 \text{ cm} \). From the Fig. 3.3(b) it is inferred that a particle must be injected nearer the mid plane for better confinement of the same.
FIG. 3.3(a). $F_{\parallel}$ as a function of $z_0$ for selected values of $B$ with initial values; $\Phi_0 = 600 \text{ V}$, $v_{\phi_0} = 0$ and $v_0 = 1 \times 10^5 \text{ ms}^{-1}$. 
FIG. 3.3(b). $F_\parallel$ as a function of $z_0$ for selected values of $\Phi_A$ with initial values; $\nu_{\phi_0} = 0$, $\nu_0 = 1 \times 10^5 \text{ ms}^{-1}$ and $B = 2 \text{ T}$.
FIG. 3.3(c). $F_J$ as a function of $z_0$ for selected values of $v_0$ with initial values; $v_{fo} = 0, \phi_A = 600$ V and $B = 2$ T.
Similar results were obtained for selected values of \( v_0 \) and illustrated (Fig. 3.3(c)). The variation of \( v_0 \) does not affect \( F_\parallel \) much.

3.2.4. Effect of injection velocity \( v_0 \).

Figs 3.4(a) to 3.4(d) illustrate the results of the effect of \( v_0 \) on \( F_\parallel \) for selected values of \( v_{\phi 0} \), \( z_0 \), \( B \) and \( \Phi_A \). The common trend of the curves is that the \( F_\parallel \) decreases linearly with increase in \( v_0 \) except for small \( z_0 \).

3.2.5. Effect of initial azimuthal component of velocity \( v_{\phi 0} \).

The results of \( F_\parallel \) as a function of \( v_{\phi 0} \) for selected values of \( z_0 \), \( B \) and \( \Phi_A \) are illustrated in Figs. 3.5(a) to 3.5(c). In general the variation is in agreement with earlier results [3]. The general pattern of variation is that \( F_\parallel \) exhibits a minimum as a function of \( v_{\phi 0} \). For selected values of \( z_0 \), the effect of \( v_{\phi 0} \) on \( F_\parallel \) is given in Fig. 3.5(a). It is seen that there exists a minimum for \( F_\parallel \), which shifts towards a higher \( v_{\phi 0} \) value for larger \( z_0 \) (the injection point is moved away from the midplane). For \( z_0 = 1, 2, 3, 4 \) and 5 cm, the minimum occurs at \( v_{\phi 0} = 0.4, 0.5, 0.6, 0.7 \) and 0.8 respectively. The minimum \( F_\parallel \) suggests that for a given \( v_{\phi 0} \), \( z_0 \) must be chosen for maximum \( F_\parallel \) for trapping of the particle.

The results for selected values of \( B \) are illustrated in Fig. 3.5(b). For the given \( B \) values a sharp minimum is not exhibited.

The \( v_{\phi 0} \) has significant effect on \( F_\parallel \) (Fig 3.5(c)). The \( F_\parallel \) exhibits a minimum as a function of \( v_{\phi 0} \). This minimum shifts towards a larger \( v_{\phi 0} \) value for a higher applied potential.
FIG. 3.4(a). Effect of $v_0$ on decelerating force $F_y$, for selected values of $v_{e0}$. Initial values: $\Phi_A = 600 \text{ V}, B = 2 \text{ T}$ and $z_0 = 5 \text{ cm}$. 

Initial velocity $(v_0) 10^5 \text{ ms}^{-1}$
FIG. 3.4(b). Effect of $v_0$ on decelerating force $F_{||}$, for selected values of $z_0$. Initial values: $\Phi_A = 600$ V, $B = 2$ T and $v_{40} = 0$. 

Initial velocity ($v_0$) $10^5$ m s$^{-1}$

- $z_0 = 1$ cm
- $z_0 = 2$ cm
- $z_0 = 3$ cm
- $z_0 = 4$ cm
- $z_0 = 5$ cm
FIG. 3.4(c). Effect of \( v_0 \) on decelerating force \( F_y \), for selected values of \( B \). Initial values: \( \Phi_A = 600 \, \text{V}, z_0 = 5 \, \text{cm} \) and \( v_{0y} = 0 \).
FIG. 3.4(d). Effect of $v_0$ on decelerating force $F_y$, for selected values of $\Phi_A$. Initial values: $B = 2\, \text{T}$, $z_0 = 5\, \text{cm}$ and $v_{\phi 0} = 0$. 

Initial velocity ($v_0$) $10^5\, \text{ms}^{-1}$
FIG. 3.5(a). $F_0$ as function of $v_{\phi_0}$ for selected values of $z_0$. Initial values: $\Phi_A = 600 \ V$, $B = 2 \ T$ and $v_0 = 1 \times 10^5 \ ms^{-1}$. 
FIG. 3.5(b). \( F_t \) as function of \( v_{\phi_0} \) for selected values of \( B \). Initial values: \( \Phi_A = 600 \), \( V, z_0 = 5 \text{ cm} \) and \( v_0 = 1 \times 10^5 \text{ ms}^{-1} \)
FIG. 3.5(c). $F_\parallel$ as function of $v_\phi_0$ for selected values of $\Phi_A$. Initial values: $z_0 = 5$ cm, $B = 2$ T and $v_0 = 1 \times 10^5$ ms$^{-1}$.
3.2.6 Effect of $B$ and $\Phi_A$ on components of $F_y$

The decelerating force $F_y$ consists of two components, viz. centrifugal component $F_c$ and a mirror component $F_m$. Figs. 3.6(a) and 3.6(b) illustrate the effect of magnetic field and applied electrostatic potential respectively on centrifugal and mirror components.

For small $B$ values $F_y$ mainly depends on $F_c$ and it steeply decreases as $B$ is increased from $0.5$ T to $B = 1.0$ T (Fig. 3.6(a)). Beyond that $B$ value, $F_c$ decreases gradually tending to a constant value. The mirror component $F_m$ has relatively a small contribution to $F_y$. At $B = 0.5$ T, $F_c = 250$ V cm$^{-1}$ and $F_m = 85$ V cm$^{-1}$. Also the $F_m$ decreases very gradually from the beginning and its contribution to $F_y$ is more than that of $F_c$ beyond $B=1.0$T. It is seen that, for larger $B$ values, $F_y$ will depend more on the mirror component.

The applied potential $\Phi_A$ gradually increases $F_c$, as well as $F_m$ as it increases. Though both the components increase approximately at equal rates, $F_c$ dominates the $F_m$ (Fig. 3.6(b)).

3.3. DISCUSSION

The results of the study on the parallel component of the retarding force $F_y$ using the Eq. (3.2) are illustrated in Figs.3.1 to 3.6. It is evident that $z_0$ is an important parameter deciding $F_y$. At large distances from the mid plane, a variation in $z_0$ has only a marginal effect on $F_y$. In the magnetoelectrostatic trap, near the axial apertures the $F_y$ mainly depends on the centrifugal component of force [3].
FIG. 3.6(a), Effect of magnetic field intensity (B) on decelerating force ($F_n$), centrifugal component of the decelerating force ($F_c$) and mirror component of the decelerating force ($F_m$)
FIG. 3.6(b). Effect of electrostatic potential ($\Phi_A$) on decelerating force ($F_\parallel$), centrifugal component of the decelerating force ($F_c$) and mirror component of the decelerating force ($F_m$)
As $B$ is increased from a small value, $F_\parallel$ falls steeply first, at a smaller rate thereafter, and finally tends to a constant (Fig 3.1). The characteristic appears to be asymptotic about the axes. The centrifugal force and mirror components are shown in figure (Fig.3.6(a)). The variation of $F_\parallel$ with $B$, keeping $\Phi_A$ and other parameters constant, is shown in Table 3.1. While $B$ increases, $F_\parallel$ decreases.

In Fig. 3.6(a), it is seen that $F_m$, the mirror component of the decelerating force decreases only to a small extent with increase in $B$. The decrease in $F_m$ with increasing $B$ from 0.1 to 2.5 T is gradual. The reason for this is due to the second term in Eq. (3.2) where $F_m$ decreases with $1/B$ and $\partial B/\partial s$ is small except at the centre of symmetry. The mirror component force should in fact depend on the geometry of the cusp.

However there is a large variation in the centrifugal component of the force for the same interval of $B$. This may be explained on the basis of the factors in the centrifugal term of the Eq. (3.2).

In the central (centre of symmetry) region, which is actually the nonadiabatic region, there is a rapid variation in $B$. Nearer the cusp apertures, the magnetic field tends to become uniform and the mirror force tends to a very small value.

$F_\parallel$ decreases rapidly as $B$ is increased, because of the presence of $B$ in the denominator of both the terms in Eq. (3.2). The centrifugal force $F_c$ falls rapidly with increase in $B$ (Fig. 3.6(a)). The first term in Eq. (3.2) contains $B^3$ in the denominator as $V_E = (E \times B)/B^2$. Hence $F_c$ will fall rapidly with increase in $B$ when the other parameters are fixed.
In the presence of an electrostatic field the flux tubes will converge and the openings can be much thinner than a Larmor radius [8]. Hence if the B increases, the r_L of the particle decreases, the particle's guiding centre follows the flux line and the particle escapes through the axial aperture.

\[ F \parallel \text{ is zero for } \Phi_A = 0 \text{ and increases with increasing } \Phi_A \text{ (Fig 3.6(b)). The rate of increase also increases at greater } \Phi_A \text{ which becomes more and more significant at higher values. The nature of variation of the centrifugal and the mirror components of forces appear to be similar. The variation of } F \parallel \text{ over a wide range of } \Phi_A \text{ is also shown in the Table 3.2, keeping B and other parameters constant.} \]

Also near the cusp aperture the potential hill rapidly falls (Fig 1.3(b), Chapter I. Hence one could expect that \( F_\parallel \) has a significant value near the cusp plane and tends to a very small value as the injection point is moved towards the axial aperture (Fig 3.1). The centrifugal force due to the crossed electric and magnetic fields will be greater at greater \( \Phi_A \) since \( V_E \) in Eq. (3.2) increases. Hence at any given injection point, \( F_\parallel \) is larger for larger \( \Phi_A \) values.

The minimum \( r_c \) (Fig 3.5) may be due to the possible minimum value of \( v_L \) (Eq. 2.22b and 2.23 c, Chapter II), which in turn will be \( V_L \) in Eq. (3.2).

The drift velocity \( V_E \) is proportional to \( \Phi_A \) due to the geometry of B and \( \Phi_A \), \( V_E \) will contribute to \( V_L \). The presence of \( V_E^2 \) and \( V_L^2 \) lead to accelerated increase in \( F_c \) and \( F_m \) with increasing \( \Phi_A \). Hence \( \Phi_A \) produces a large decelerating force as observed in Fig 3.6(b) and also in Table 3.2.
Table 3.1. Decelerating force versus magnetic Field
($z_o = 5 \text{ cm}, v_o = 1 \times 10^5 \text{ m s}^{-1}, v_0 = 0, \Phi_A = 1000 \text{ V}$).

<table>
<thead>
<tr>
<th>B (Tesla)</th>
<th>$(1/e) F_{\parallel} (\text{V cm}^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>320</td>
</tr>
<tr>
<td>1.0</td>
<td>140</td>
</tr>
<tr>
<td>1.5</td>
<td>80</td>
</tr>
<tr>
<td>2.0</td>
<td>50</td>
</tr>
<tr>
<td>2.5</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 3.2. Decelerating force versus applied potential
($z_o = 5 \text{ cm}, v_o = 1 \times 10^5 \text{ m s}^{-1}, v_0 = 0, B = 1 \text{ T}$).

<table>
<thead>
<tr>
<th>$\Phi_A$ (Volts)</th>
<th>$(1/e) F_{\parallel} (\text{V cm}^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>35</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>750</td>
<td>190</td>
</tr>
<tr>
<td>1000</td>
<td>320</td>
</tr>
<tr>
<td>1250</td>
<td>480</td>
</tr>
</tbody>
</table>
3.4. CONCLUSION

The decelerating force acting on a positive ion in a cusped magnetic field configuration with electrostatic stopper at the cusp ends has been studied by numerical methods as a function of $z_0$, $v_0$, $v_{40}$, $B$ and $\Phi_A$. The force was found to be strongly dependent on $z_0$, $v_{40}$, $B$ and $\Phi_A$. It may be concluded that an applied electrostatic potential at the cusp aperture will greatly enhance plasma confinement in a cusped field configuration.
REFERENCES

1. Lavrent'ev O. A., Ukr Zh Fiz., 8 (1963) 440, (See also Culham Laboratory Translations. CTO 217 and 218, July).


