*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-5.006 (2004)*

Insulator length effects in Mather-Type Plasma Focus Device

[1]H.R.Yousefi, [2] G.R. Etaati, [1]M. Ghorannevis

[1]*Plasma physics research center, I.A.University.P.O.Box 14665-944, Tehran,Iran*
[2] *Institute of Applied Physic, P.O.box 15875-5878, Tehran, Iran*

Abstract: It was determined a modification factor "$F > [(C^2-1)/ 2LnC]^{½}$ " for axial velocity in different devices. By plotting the current sheath curvature for different insulator lengths in a PF device and comparing the neutron yield for them, it seems for the case of L_{ins}= b neutron yield is the highest.

Keywords: Plasma focus, insulator sleeve, Run-down phase, current sheath, breakdown phase

1. Introduction

In a plasma focus a number of factors must come together to make the device work properly, such as geometry of electrodes, geometry of insulator sleeve, type and pressure of filling gas, rate of discharge current rise, and electrode polarity. The insulator that surrounds the first part of the inner electrode has an important role in the plasma focus dynamics. Formation of the current sheath and pinch dynamics strongly depends on the insulator sleeve length as well as the curvature of current sheath. As results when the insulator is not of appropriate length, the current sheath no longer remains uniform, and the so-called filaments or spokes are developed [4]. Kies [5] reported that the filaments in the current sheath can be avoided by conditioning the sleeve surface. In our last paper [1] we investigated more than twenty PF devices with different energies and deduced a limit for design of insulator length in Table1.We found that the scaling parameter can be defined as L_{ins}/b-a which takes values between from 1 to 1.8.Where b is the inner radius of the cathode, a is the outer radius of the anode and L_{ins} is the insulator length.

2. Theoretical considerations

Since changing insulator length actually points to the curvature of current sheath; we have tried to finding a correlation between curvature of current sheath and neutron yield. The discharge stays near the insulator surface for about 300 ns. Then it expands radial and axially.

During the rundown phase the plasma sheath has a parabolic contour which is described [6] by

$$Z(r) = -\frac{a}{2q}\left[x(x-q^2)^{1/2} - (1-q^2)^{1/2} - q^2 \mathrm{Ln}\frac{x+(x^2-q^2)^{1/2}}{1+(1-q^2)^{1/2}}\right] \qquad (1)$$

With x = r/a

$$q = (\mu_0 I^2/8\pi^2 a^2 \rho_0 u^2)^{1/2} \qquad (2)$$

r the distance from the axis, a the radius of the center electrode, ρ_0 the density of the undisturbed gas, I the current in the plasma sheath, u the velocity of the sheath. The measured parameter q is approximately equal to unit. Hence q can be considered as a scaling parameter for the rundown phase of Mather type plasma focus devices. Thus we have calculated the parameter q for some devices by using of eqs. (3) In eqs. (2) But they have been larger than unite, whereas this is the contradictory to G.herziger [7] refer to this range which included 0.5<q<1. As it is known that the mass swept up by the current sheath is not %100 of the mass encountered so that the "effective" gas density is actually less [2]. Whereas in the snow plow model, the axial speed is equal to:

$$V_a = \left[\frac{\mu \mathrm{LnC}}{4\pi^2(C^2-1)}\right]^{1/2} \frac{I_0}{a\sqrt{\rho}}, \qquad C=b/a \qquad (3)$$

It seems that we should consider a modification factor for velocity due to that only a little of all mass swept up by current sheath. In the constant energy, the velocity of current sheath is proportional to inverse of square root of mass and is proportional to current. Therefore if we considered these parameters; f_c and f_m in the snow plow model then the axial speed will be:

$U_a = FV_a$ and $F = \frac{f_c}{\sqrt{f_m}}$.

Thus: $$U_a = \frac{f_c}{\sqrt{f_m}}\left[\frac{\mu LnC}{4\pi^2(C^2-1)}\right]^{1/2} \frac{I_0}{a\sqrt{\rho}} \qquad (4)$$

Where f_m is some percent of mass was sweeping by current sheath and f_c is some percent of bank current was driving the plasma sheath. Instead of V_a in the following we shall use of U_a By using of eqs. (4) In eqs. (2) We will get parameter ‘q’ on the range of 0.5<q<1.

$$q = [(C^2-1)/ 2F^2 \mathrm{LnC}]^{1/2} \qquad (5)$$

Since q should be less than 1 then:

$$F > [(C^2-1)/ 2LnC]^{1/2} \quad (6)$$

That means, with employment this factor, parameter q for all focus devices is in a range of between one and zero. In the table 1 have been determined this factor for some of plasma focus devices.

3. Results and Discussion

Strictly speaking, in this paper we have introduced a new model for plasma focus devices, which operated on optimum regimes. In this model a correlation between the inner radius of the cathode, the outer radius of the anode and the insulator length is obtained in order to modify the axial speed in the snowplow model. As it is shown in table 1, there are limited range for modification factor,

$$1.3 < F = \frac{f_c}{\sqrt{f_m}} < 2.2 \cdot$$

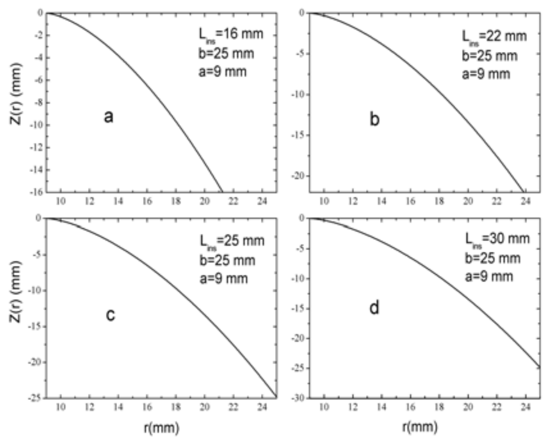

Figure.2 Current sheathe curvature for a device [3] With constant dimension and four different insulator lengths

This range ensures that parameter q for every device will be less than one. The profile of current sheath is plotted using eqs.1 (with q=1) in a device with constant dimension and four different insulator lengths (see Fig.2). As Zakaullah [3] had investigated the neutron yield in optimum condition were approximately 6×10^7, 1.7×10^8, 2×10^8, 8×10^7 for insulator lengths 16, 22, 25, 30 respectively. These result indicated that neutron yield for insulator length of 25 mm is the highest. Figure (2) from (a) to (d) shows that with increase the insulator length the end of parabolic is going to higher. Therefore, it is observed that whenever the ratio of insulator length to inner radius cathode (L_{ins}/b) is deviated from the unit value the neutron yield is decreased. This result is good agreed with our insulator length's range (table1, ref.10, 11).

Table1: List of characteristics data for various Mather-Type PF devices [1]

Mather-Type PF devices	W_0 (kJ)	V_0 (kV)	a(mm)	b(mm)	L_{ins}	$\frac{L_{ins}}{b-a}$	Min < L_{ins} < Max		$\frac{C^2-1}{2\ln C}$	$F=\frac{f_c}{\sqrt{f_m}}$
							Min	Max		
Reference (5)	?	20	10.5	25	25	1.7	14.5	26	1.6	F> 1.6
Reference (4)	2.2	25	10.5	36	45	1.8	25.5	46	2.1	F> 2.1
Reference (7)	1	22	8.5	25	25	1.5	16.5	29	1.8	F> 1.8
Reference(11)	2.3	12	9	25	25	1.5	16	29	1.8	F> 1.8
Reference(8)	2.2	25	10.5	40.5	45	1.5	30	54	2.2	F> 2.2
PFII(9)	4.7	30	18	36	35	1.9	18	34	1.5	F> 1.5
Reference(12)	7	25	17.5	40	26	1.1	22.5	40	1.6	F> 1.6
Reference (1)	3.3	15	9.5	32	27	1.2	22.5	40	2	F> 2
Reference(10)	2.3	12	9	25	16	1	16	29	1.8	F> 1.8
Reference(10)	2.3	12	9	25	22	1.3	16	29	1.8	F> 1.8
Reference(10)	2.3	12	9	25	30	1.8	16	29	1.8	F> 1.8
Reference (6)	4.7	30	19	42	35	1.5	23	41	1.6	F> 1.6
Reference(13)	700	25	48	76.5	45	1.5	28.5	51	1.3	F> 1.3
KPF-1M(15)	40	25	25	50	30	1.2	25	45	1.5	F> 1.5
Reference(16)	1.8	38	10	22.5	20	1.6	12	22.5	1.6	F> 1.6
CPF-1M(17)	40	25	40	65	30	1.2	25	45	1.3	F> 1.3
Reference(18)	200	20	50	100	63	1.2	50	90	1.5	F> 1.5
Reference(19)	2.3	12	9	25	25	1.5	16	29	1.8	F> 1.8
Reference(20)	2.3	12	9	28.8	25	1.2	20	36	2	F> 2
DPF-40(21)	18	20	32	59	35	1.3	27	49	1.4	F> 1.4
ICN-UNAM(22)	3.3	30	20	50	30	1	30	54	1.7	F> 1.7

Reference:

[1]H.R.Yousefi and et.al. Int. Toki. Conf. Procceeding, 2003, Japan.

[2]S.Lee and Adrian Serban.IEEE Transaction on Plasma Sci.24, No.3, 1101(1996)

[3]M.Zakaullah and etal.Physics.Letters A.137, 39 (1989)

[4] M.Zakaullah and et al.Plasma Source Sci.Techno.4 (1995) 117-124

[5] W.Kies.Plasma Pysics and Controlled Fusion, 28, No.11, 1645-1657 (1986)

[6] H.Krompholz.Phys.letters, 77A, No.4 (1980)

[7] G.Harziger and et al.Physi.Letters, 71 A, No.1 (1979)