

Comparison the Results of Numerical Simulation And Experimental Results for Amirkabir Plasma Focus Facility

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Abstract In this paper the results of the numerical simulation for Amirkabir Mather-type Plasma Focus Facility (16 kV, 36 μ F and 115 nH) in several experiments with Argon as working gas at different working conditions (different discharge voltages and gas pressures) have been presented and compared with the experimental results. Two different models have been used for simulation: five-phase model of Lee and lumped parameter model of Gonzalez. It is seen that the results (optimum pressures and current signals) of the Lee model at different working conditions show better agreement than lumped parameter model with experimental values.

1. Introduction

The Plasma Focus devices have been developed independently in 1960's in two different models by Filippov in Soviet Union and Mather in United States [1, 2]. Today many samples of both models in the range of tens of joules to some Megajoules are working in different research centers all over the world [1–7], and the technical problems about design and construction of them are solved completely, but the theoretical description of these devices is very complicated and there is not any proper model for explanation of all of their working phases [2, 7, 8].

In general, the different phases of discharge in Plasma Focus devices can be divided to five different stages [2, 7, 9]: 1 – The initial breakdown and surface discharge, very little is known about the physics of this phase [10], 2 – rundown phase that does not exist in Filippov-type devices, 3 – radial compression, 4 – pinch phase, 5 – instability happening and pinch destruction.

For explanation of rundown and radial compression phases there are no difficulty but there is not any complete and reliable model for description of pinch phase and after that [2, 7–9]. For rundown and radial compression phases some different models are presented that the most acceptable of them are 2 models that the first one is presented by S. Lee that uses the equivalent circuit of the Plasma Focus with a snowplow model for rundown phase and a slug model for radial compression phase [2, 8] and the second model is presented recently by J. H. Gonzalez on the base of lumped parameters [7, 10].



In this paper, The results of these models (discharge current (I) and current derivative (dI/dt) signals, I_{\max} and t_{\max} , pinch time (t_p) and I_{t_p}) for Amirkabir Mather-type Plasma Focus device "APF"(16 kV, 36 μ F and 115 nH) for different values of gas sweeping efficiency factor (f_m) and current efficiency factor in run down phase (f_c) and gas sweeping efficiency factor (f_{mr}) and current efficiency factor (f_{cr}) in radial compression phase in the case of using Ar as working gas at different working conditions (different discharge voltages and different initial pressures) have been compared with experimental results. It has been observed that the best agreement between the results of simulation and experimental data would achieve by using the Lee model.

2. Experimental Set-up

The description of "APF" has been reported elsewhere (Table 1) [11]. The diagnostic system consists of: Two 100 MHz and 400 MHz PC-based oscilloscopes, two Rogowski coil for measuring the total discharge current & current derivative signals. NaI scintillator to register hard X-ray yield, plastic scintillator + photomultiplier to register hard X-ray & neutron signals, a pinhole camera to study soft X-ray and hard X-ray emission zones, magnetic probes to study the dynamics of current sheath in the axial phase, and faraday cup to investigate ion emissions.

Table 1. Parameters of Amirkabir PF

Symbol	Parameter	Value
R_i	Anode Radius	1.39 cm
R_e	Cathode Radius	4.47 cm
Z_0	Anode Length	14.8 cm
C_0	Capacity	36 μ F
L_0	External Inductance	115 nH
R_0	Stray Resistance	0 m Ω

3. Results and Discussion

The equations of Lee & Gonzales models have been completely described in a lot of references [2, 8–11], here we only present the numerical results of using them for Amirkabir Plasma Focus (APF). For numerically solving the equations of these models for this device, we have used a step-by-step method with MATLAB 6.5 code. Here we have compared some results of predictions of these models (discharge current (I) signal, the pinch time (t_p) at different initial pressures and discharge voltages and optimum pressure at different discharge voltages) for "APF" with Ar as working gas for different values of f_c , f_{cr} , f_m and f_{mr} with experimental results. It is observed from the comparison of the experimental results by the results of two models for several groups of the values of f_c , f_{cr} , f_m and f_{mr} that the results of two model are very close together but the Lee model is a little more compatible with experimental results than lumped parameter model (figures 1,2), to calculation the proper factors for model, several experimental results in different working conditions have been compared with the results of the simulation with different factors and finally it is observed that the results of the model for $f_m = 0.02$, $f_{mr} = 0.15$, $f_c = 0.75$ and $f_{cr} = 0.7$ have the best agreement with experimental results.

In tables 3–5 the predictions of this model for these optimum values of f_c , f_{cr} , f_m and have been compared with experimental data. One can observe that the results of the model for these values have very good agreement with experiment.

Table 2. The best factors with Argon in Amirkabir PF

Symbol	Parameter	Value
f_m	Axial Sweep Efficiency	0.02
f_c	Axial Current Efficiency	0.75
f_{mr}	Radial Sweep Efficiency	0.15
f_{cr}	Radial Current Efficiency	0.7

Table 3. Optimum pressure vs. charge voltage

Charge Voltage [kV]	Optimum Pressure [Torr]			Charge Voltage [kV]	Optimum Pressure [Torr]		
	Measured	Computed	$E_{rel} \%$		Measured	Computed	$E_{rel} \%$
10.5	0.952	0.89	6.56	13.0	1.359	1.36	0.09
11.0	1.048	0.98	6.52	13.5	1.506	1.47	2.39
11.5	1.210	1.07	11.59	14.0	1.558	1.58	1.41
12.0	1.255	1.16	7.56	14.5	1.617	1.70	5.12
12.5	1.344	1.26	6.22	15.0	1.662	1.82	9.51

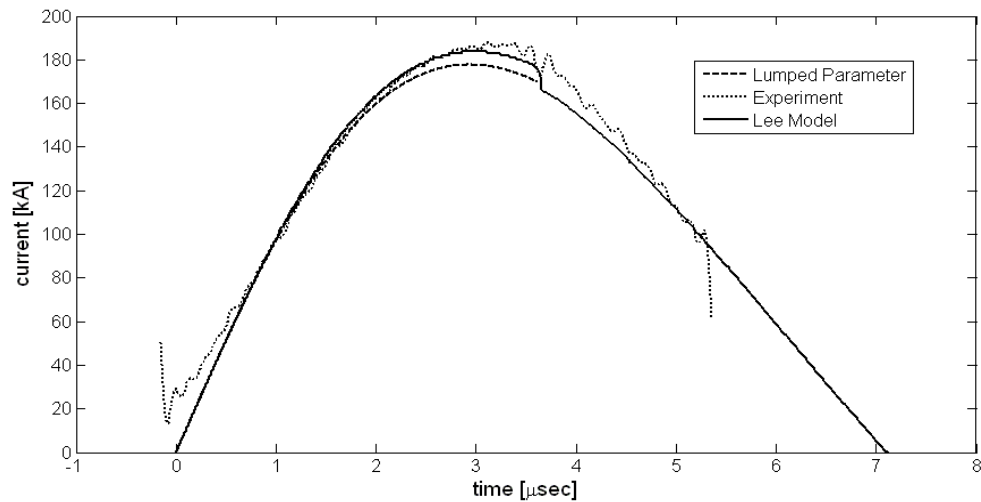


Figure 1. Total current for $P_0=1.8$ torr and $V_0=12$ kV

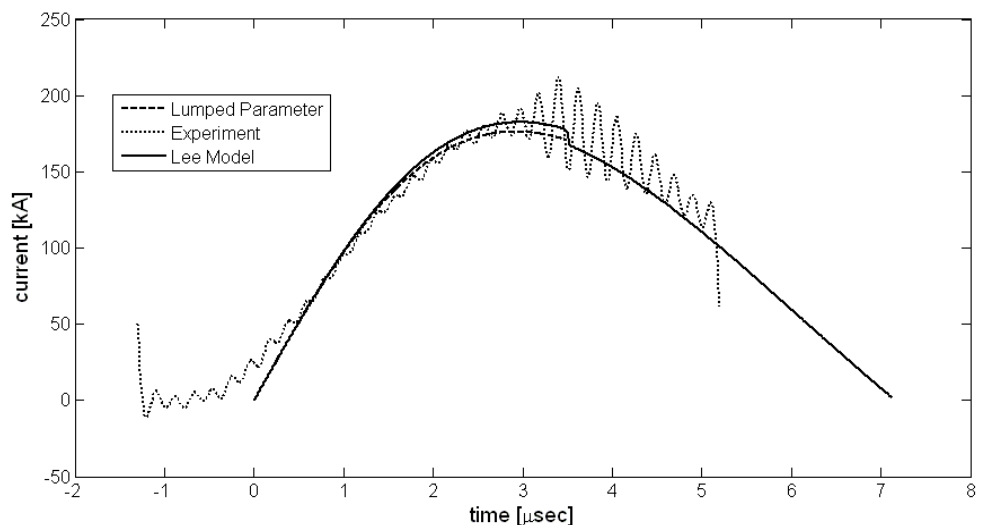


Figure 2. Total current for $P_0=1.6$ torr and $V_0=12$ kV

Table 4. Pinch current vs. charge voltage in optimum pressure

Charge Voltage [kV]	Pinch Current [kA]			Charge Voltage [kV]	Pinch Current [kA]		
	Measured	Computed	$E_{rel} \%$		Measured	Computed	$E_{rel} \%$
10.5	102.574	104.194	1.58	13.0	127.985	128.893	0.71
11.0	107.505	109.244	1.62	13.5	132.911	133.872	0.72
11.5	109.759	114.171	4.02	14.0	138.611	138.673	0.04
12.0	116.979	119.162	1.87	14.5	140.482	143.626	2.24
12.5	126.115	124.153	1.56	15.0	145.793	148.229	1.67

Table 5. Pinch time vs. operation pressure

Charge Voltage $V_0 = 11.5$ kV				Charge Voltage $V_0 = 13.5$ kV			
Operation Pressure [Torr]	Pinch Time [μ sec]			Operation Pressure [Torr]	Pinch Time [μ sec]		
	Measured	Computed	$E_{rel} \%$		Measured	Computed	$E_{rel} \%$
0.8	3.111	2.942	5.43	0.8	3.042	2.684	11.77
1.0	3.209	3.133	2.38	1.0	3.101	2.858	7.85
1.2	3.329	3.314	0.44	1.2	3.210	3.016	6.01
1.4	3.412	3.473	1.78	1.4	3.280	3.154	3.85
1.6	3.484	3.613	3.71	1.6	3.330	3.281	1.44
1.8	3.550	3.753	5.75	1.8	3.459	3.398	1.76

4. Conclusions

Two models on the base of lumped parameters for description of the operation of Mather-type Plasma Focus devices from the end of breakdown phase until the pinch time are presented, Lee model & the lumped parameter model (Gonzalez model). It is seen that the predictions of the first model for "APF" Plasma Focus device with Ar as working gas at different discharge voltages and different initial pressures have shown better agreement than the second model with experimental results and the best values of gas sweeping efficiency factors in rundown & radial compression phase (f_m , f_{mr}) and current efficiency factors (f_c , f_{cr}) in several working conditions have been found. It must be noted that these values are calculated only for Argon as working gas. The main reasons of the differences between the experimental results are that the real values of f_c , f_{cr} , f_m and f_{mr} are not constant in different experiments and the surface discharge and breakdown phase has been neglected in it.

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