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COMPARISON OF MEASURED AND COMPUTED NEUTRON YIELD VERSUS PRESSURE CURVE ON NX2 AT DIFFERENT OPERATING VOLTAGES

Prakash Gautam*, Raju Khanal
Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu, Nepal

*Corresponding author's e-mail: om.gautam49501@gmail.com

ABSTRACT
Numerical experiments are carried out using the Lee model code to compute the neutron yield of NX2 as a function of pressure. Results are compared with the published data (measured) and comparison shows good agreement for maximum neutron yield and for the range of the gas pressure. Measured neutron yield for operating voltage 14.5 kV is larger by factor 2 but operating voltages 10.5 kV and 12.5 kV is larger by more than factor 2.

Key words: dense plasma focus, Lee model code, neutron yield

INTRODUCTION
The dense plasma focus (DPF) is a coaxial gun, with the inner electrode, the anode, is electrically insulated from the outer electrode, cathode. After achieving a high vacuum condition, desired gas is admitted at a pressure of a few millibar or torr. The plasma is originated when capacitor bank is discharged through a low inductance transmission line (as spark or rail gap switches are closed) within very short interval of rise time in the range of ns [1]. The DPF produces abundant multi-radiation, a wide spectrum of photons and particles and is the subject of many studies and applications. From many devices and experiments performed a large set of data and information have been collected. The data and information lead to interesting discussions [2].

The Lee model code couples the electrical circuit with plasma focus, thermodynamics and radiation, enabling realistic simulation of all gross focus properties. The basic model described in 1984 [3], was successfully used to assist several experiments [4]. The radiation-coupled dynamics was included in 5-phase code, which is successful to lead numerical experiments on radiation cooling [5]. Reflected shock and radiativephase are added to the earlier model to simulate the x-ray emission from the plasma focus [6]. The signal-delay slug was incorporated together with real gas thermodynamics and radiation-yield terms, which is so crucial to radial simulation and assisted other research projects [7-9] and web published in 2000 [10] and 2005 [11]. All subsequent versions of Lee code are improved versions and signal delay slug is incorporated as a must have feature. Plasma self- absorption was included [10] in 2007, improving soft x-ray yield simulation. The code has been used extensively as a complementary facility in several machines, such as; UNU/ICTP PFF [4, 8, 12], NX2 [7, 9], NX1 [9]. Information obtained includes axial and radial dynamics [12], SXR emission characteristics and yield [8, 9], design of machines [4, 8, 9, 12], optimization of machines [8, 9, 12] together with the adaptation of the Filippov-type DENA [13]. Plasma focus SXR yield

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calculations [14], pinch current and SXR yield limitations [15], optimization of SXR yield [14 ,15], radiative collapse and cooling [16], line radiation [17], current stepped PF[18], PF neutron yield calculations [19], current and neutron yield limitations [20], neutron saturation [21] and extraction of diagnostic data [22] and the anomalous resistance phase(RAN) data [23] from the current signals have been studied applying the code [24]. Speed-enhanced PF [25] was facilitated. The inclusion of the neutron yield, Y_n, using beam target mechanism [19] is one the great step in the development, incorporated in the versions [24] of the code (later than RADPF5.13), resulting in realistic Y_n scaling with I_{pinch} [19].

PROCEDURES FOR THE NUMERICAL EXPERIMENTS

The Lee Model Code is configured to work as any plasma focus by providing the tube parameters b, a, and z_0; the bank parameters, L_0, C_0 and the stray resistance r_0 and operational parameters V_0 and $P_0$and thegas fill. The tube parameter of the device shows the size of tube used in the plasma focus device, bank parameters shows the capacity of the inductor, capacitance and the resistance used in the combination of circuit of device and operational parameter are operating voltage and the pressure of gas used there. The standard practice to fit the total discharge current waveform to experimentally measured value is done by adjusting the four model parameters: axial mass swept-up factor (f_m) and axial current factor (f_c) and radial mass swept-up factor (f_{mr}) and radial plasma current factor (f_{cr})[24]. It is seen and known that the current trace of the focus is the best indicator of the gross performance of the focus device. Important information like axial and the radial phase dynamics and the essential energy transfer are quickly visible from the current trace, which shows the importance of the fitting of the current trace [24].

FITTING THE NUMERICALLY COMPUTED CURRENT TRACE TO OBTAIN THE MODEL PARAMETERS

The NX2 is a repetitive plasma focus which was originally designed as a high performance neon soft x-ray SXR source for microlithography. It has been re-designed to operate as a neutron source as well. Koh et al had published a paper with laboratory measurements from the NX2-T, including information on neutron yield (Yn) at different pressuresoperating at various voltages with effective lengths 2.5 cm to 4.5 cm [27]. We obtain current waveform data from [28]. We first fit the computed current waveform to the measured waveform.

We configure the Lee code (version RADPF5.15de) to operate as the NX2-T starting with the accessible parameters z_0 = 4.5 cm, V_0 = 14.5 kV, andP_0 = 15.2 torr Deuterium from [26, 28]. To obtain a reasonably good fit in case of NX2-T the following bank and tube parameters (L_0, C_0, z_0 and r_0) were used;

Bank parameters:	L_0 = 20nH,	C_0 = 28μF,	r_0 = 2.7 mΩ
Tube parameters:	b = 3.8 cm,	a = 1.55 cm,	z_0 = 4.5 cm
Operating parameters:	V_0 = 14.5 kV,	P_0 = 15.2torr Deuterium	
Tapered anode:	taper start=1 cm and end radius=1.15 cm		

Together with the model parameters: f_m = 0.11, f_c = 0.7,
f_{mr} = 0.38 and f_{cr} = 0.75

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where, L_0 is the static inductance, C_0 is the storage capacitance, b is the tube outer radius, a is the inner radius, z_0 the anode length, V_0 the operating voltage and P_0 the operating initial pressure.

The Numerically computed total discharge current waveform is fitted with the measured by adjusting the model parameters f_m, f_c, f_{mr} and f_{cr} one by one until the numerically computed waveform agrees with measured waveform. First, to adjust the rising slope and the rounding off the peak current the axial model parameters f_m and f_c are adjusted and then to adjust the computed slope and depth of the dip the radial parameters f_{mr} and f_{cr} are fitted. This process is case sensitive in that if any bank parameter such as L_0 or C_0 is not correctly given, no good fit is obtainable (which affect all results in plasma dynamics).The fitted computed current curve fits well with the measured waveform as shown in figure 1, which shows good agreement, and fit is good at the regions of interest, i.e., from axial phase up to the end of the radial phase.

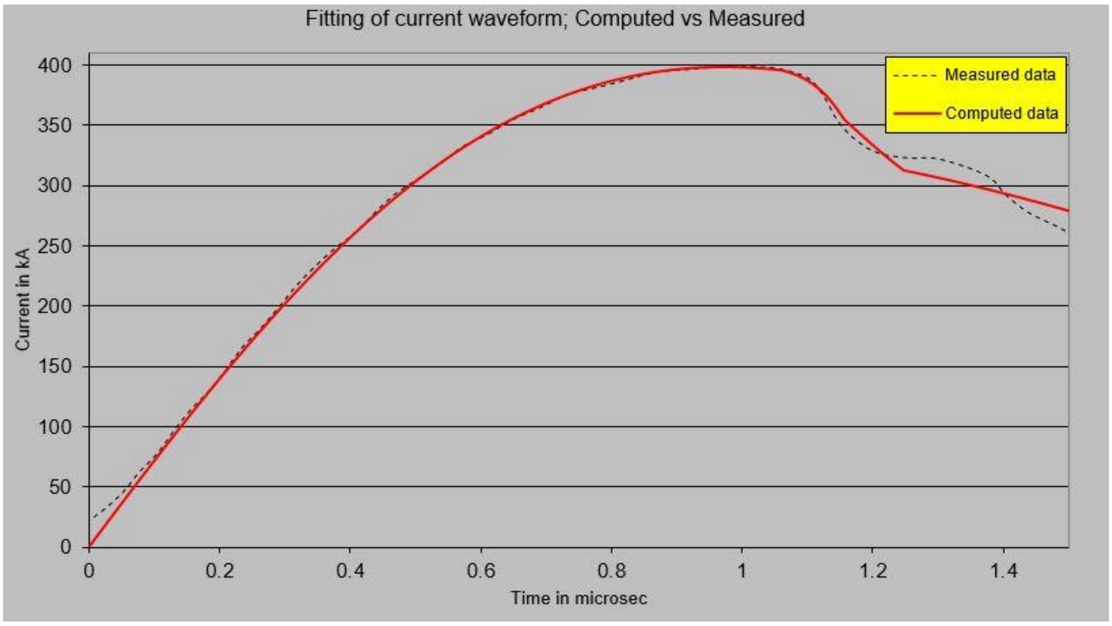

Figure 1: Computed discharge current compared with the measured current waveform [6]

COMPUTING THE NEUTRON YIELD AS A FUNCTION OF OPERATING PRESSURE

The code is configured to operate as the NX2 using the bank and the tube parameters mentioned above and using the fitted model parameters. Numerical experiments are then carried out at various initial pressures in deuterium. The Y_n are than plotted in figure 2 and compared with the published Y_n [27], which shows agreement with the published curve in terms of the general shape with the computed value of Y_n occurring at 19.3 mbar compared to the measured peak value occurring at 19.75 mbar for 14.5 kV; where the peak measured is twice of the computed value, the general shape with computed value of Y_n occurring at 13.93 mbar compared to the measured peak value occurring at 13.33 mbar for 12.5 kV; where the peak measured value is near about 2.5 times the computed value and the general shape with

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the computed value of Y_n occurring at 8 mbar compared to the peak measured value occurring at 10 mbar for 10.5 kV; which is near about 3.5 times the computed peak value.

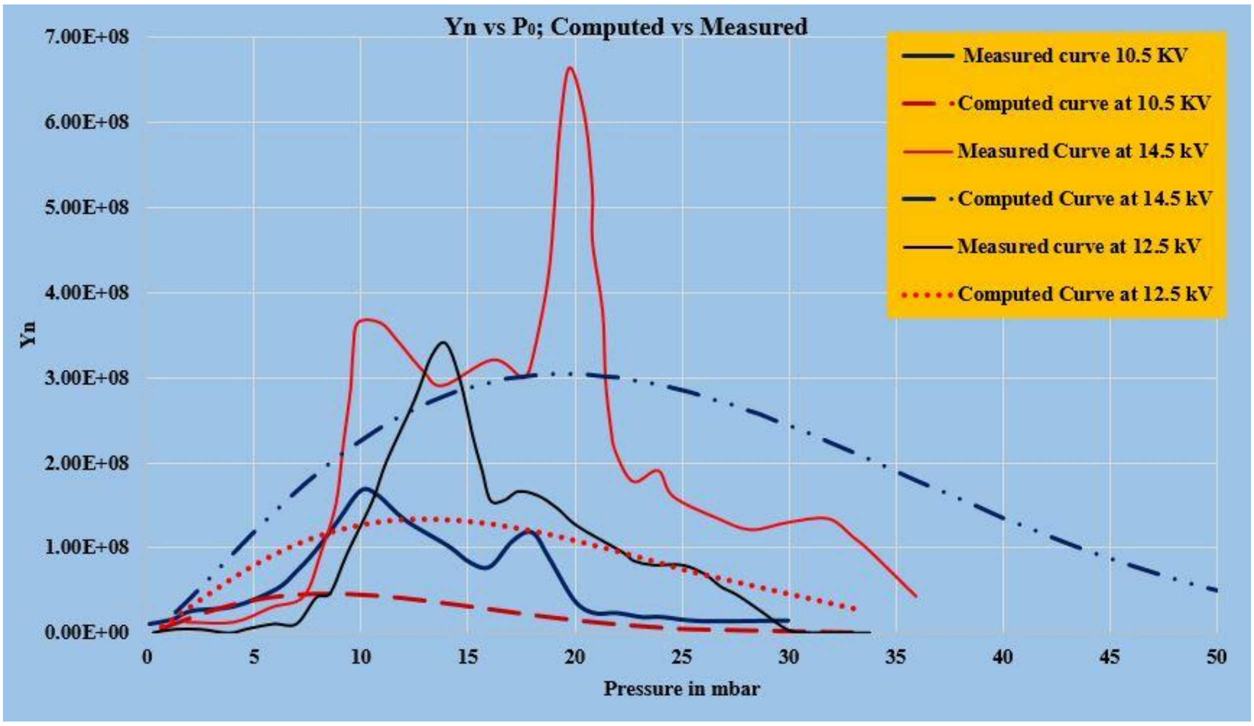

Fig.2: Computed and Measured Neutron Yield as function of pressure

CONCLUSION

In this paper we have analyzed the computed neutron yield versus pressure curve of Singaporean plasma focus device NX2 (with re-designed electrode). . The graph shows the gentler slope on the either side of the maximum yield. The results agree with the measured data in term of the range of the pressure and the point of the maximum yield. The reduction of factor of computed neutron yield from 14.5 kV to 10.5 kV compared to measured neutron yield may because of the choice of the operating voltage while finding the model parameters.

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