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The Effect Of Insert Anode Shape On The Characteristics Of Neutron Emission In A Filippov-Type Plasma Focus

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Abstract An extensive comparative theoretical and experimental study was carried out with the aim of identifying the effect of the insert anode shape, flat and conic, on the characteristics of the neutron emission produced in a deuterium and deuterium-krypton mixture plasmas. The theoretical study is based on the snow-plow model and shock wave theory. The experiments were carried out on a new Filippov type plasma focus device “Dena” (288μF, 25kV, 90kJ) with a constant discharge voltage of 18kV. It was found that, the total neutron emission yield is high within a narrow pressure range using a conic insert, while for the flat insert; this was in a wider range. Furthermore, with deuterium krypton mixture, the optimum pressure range for the conic insert also was higher. In this measurement, the total neutron yield increases by a factor of 3.7 for a flat and 5.7 for a conic insert anode. The experimental results show that, the krypton admixture can amplify the thermal mechanism regime of the fusion neutron production and is in a good agreement with the theoretical calculations.

1. Introduction

Plasma focus is a phenomenon occurring at the open end of coaxial electrodes when an intense electrical discharge between them is induced through a switch (spark gap) by an external capacitor bank. In comparison to the other fusion devices the plasma focus is one of the most efficient neutron sources, which combines high neutron fluxes up to 10^{20} neutrons/s. Since the pioneer work Filippov [1] and Mather [2], plasma focus has been extensively studied by many researchers aiming to increase the neutron emission [3]. In spite of the difference between Filippov and Mather types in term of gas pressure range (0.1 to 10 mbar for Mather type and 0.5 to 2 mbar for Filippov type [5]), a strong influence on the plasma focus neutron emission is produced by the gas composition, gas pressure and electrodes structure [6-7]. In this paper, we compare the experimental results with the theoretical model based on snow-plow and shock wave theory, by considering the effects of insert anode shapes on neutron production in different gas pressures and compositions.

2. Plasma focus dynamics with conic and flat insert anodes

The motion of the current sheaths (CS) is similar in both flat and conic inserts, before they cross the radius of the insert anode, r_0. This motion will be elongated axially after r_0, in **+Z** and $\pm$**Z** directions in the case of the flat and conic insert anodes, respectively. The radial speed of CS can be written as

$$\upsilon_r^2 = k I^2/\rho \tag{1}$$

Where k is the constant and I is the current and ρ is the ambient gas density. Once the radial speeds of CS in conic and flat are compared, the resulting equation is

$$\frac{dr_1}{dr_2} = (\frac{r_1}{r_2})(\frac{h_1}{h_1 + h_2})^{1/2} \tag{2}$$

Where r_1 and r_2 are the CS radial position in flat and conic, h_1 and h_2 are elongation length of CS in **+Z** and **–Z** directions, respectively. By integrating the eq. (2) we have

$$\frac{r_2}{r_1} = (\frac{r_1}{r_0})^{[(\frac{h_1+h_2}{h_1})^{1/2}-1]} \tag{3}$$

Resulting to $r_2 < r_1$. To synchronize the time of pinch occurrence t* with the current rise time, we need to calculate the time of shock wave motion from r_0 to r*, where r* is the position of reflected shock wave and CS meeting. Using the shock wave theory

$$\upsilon_s^2 = \frac{\mu(\gamma+1)}{16\pi^2\rho_0}\frac{I^2}{r^2} \tag{4}$$

Where υ_s and r are the shock speed and radial position of CS respectively, we can write

$$\frac{\upsilon_{s1}(flat)}{\upsilon_{s2}(conic)} = \frac{r_2}{r_1} < 1 \tag{5}$$

From the eqs. (3) and (5) one can see that the pinch o ccurrence in the conic is more rapid and consequently, we need to increase the ambient gas density (see eqs.(1), (4)) for obtaining an optimum timing. To calculate the required gas density increasing, we have to obtain the time difference of the pinch occurrence between flat and conic. Using eq. (5) one can obtain

$$\Delta t \approx \frac{r_0 + r_1{}^*}{\overline{\upsilon_{s1}}}[1 - (\frac{r_1{}^*}{r_0})^{[(\frac{h_1+h_2}{h_1})^{1/2}-1]}] \tag{6}$$

Where $\overline{\upsilon_{s1}}$ is the average shock velocity, that is $\frac{\int_0^{t^*}\upsilon_{s1}dt}{t^*}$ and $t = 0$ is correspond to $r = r_0$.

Using the eqs. (1) and (4) one can obtain $\frac{d\upsilon_s}{\upsilon_s} = -\frac{1}{2}\frac{d\rho}{\rho}$ therefore, $\frac{d\rho}{\rho} = 2\frac{dt}{t}$.

To estimate the time difference Δt in our device, we have used $((h_1 + h_2)/h_1)^{1/2}$ = **1.366,** $r_1{*}/r_0 \approx$ **0.2** and $\overline{\upsilon_{s1}}$ ~ **1.5 – 2.5×10^6 cm/s,** resulting to $\Delta\rho/\rho =$ **22% - 36%**.

3. Experimental setup

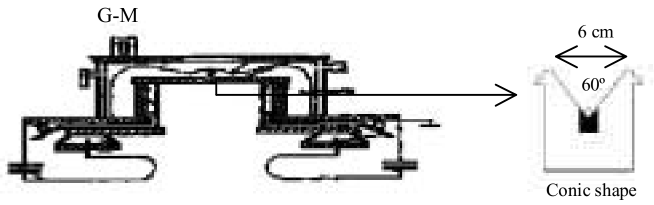

Fig. 1.The schematic diagram of electrodes

The experiment is conducted on a Filippov-type plasma focus "Dena" energized by a 288 μF capacitor bank and charged up to 20 kV giving a maximum discharge current of about 2 MA with a short circuit rise time of 4 μs. The schematic arrangement of the electrode and diagnostic system is given in Fig. 1. Two different insert anodes, flat and conic are employed. The discharge current and its derivative signals are measured by a Rogowski coil and a magnetic probe respectively, which are recorded simultaneously by a two channel 500 MHz Tektronix oscilloscopes. An In foiled Geiger-Muller counter which has located at 50º angle to the axis and 30 cm far from center of insert anode was used for time-integrated measurements of neutron emission.

3. Result and discussion

For the two-insert anode configuration, we have changed the deuterium filling pressure from 0.2 to 1.5 torr and krypton admixture from 0 to 3.5%. Fig. 2 shows the neutron yield as a function of deuterium filling pressure with conic and flat insert anodes. As it can be seen, the optimum pressure ranges are 0.6 – 0.85 torr and 0.85 – 1.0 torr for flat and coni c insert anode shapes, respectively. We observe that the maximum neutron yield, employing the conic insert anode, is obtained at the higher pressures (almost 27% above flat case) in a narrow range compared to the flat insert anode, as expected. In Fig. 3, we have shown the same comparison for a deuterium+1% krypton mixture. While the optimum pressure range using the flat insert anode is similar to the previous case (only deuterium gas), the optimum pressure for the conic shape is increased towards higher pressure (1.15 – 1.25 torr). The effect of krypton admixture in neutron emission enhancement is notable. As is evident from Fig. 4, the maximum neutron yield is obtained by adding krypton admixture of about 1% and 1.5% to the deuterium gas, in the case of conic and flat, respectively. In Fig. 5 we have shown the neutron yield versus the discharge voltage for the two working gases employing two insert anode shapes. The results strongly verify that the krypton has not been mixed with the working gas homogenously, and we should look for the clue of its effects on the pinch dynamics. According to the experimental scaling law ($Y_n \sim I^{\alpha}$), the parameter α has been

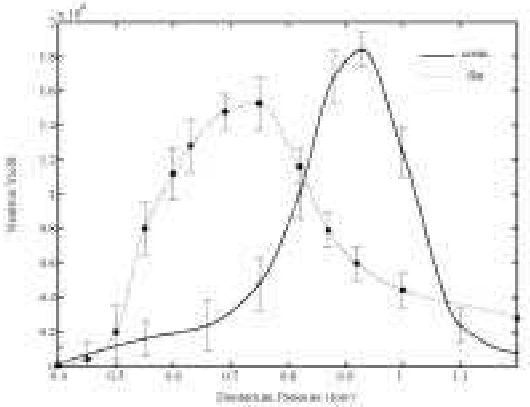

Fig. 2. Neutron yield as a function of deuterium pressure with conic and flat insert anodes.

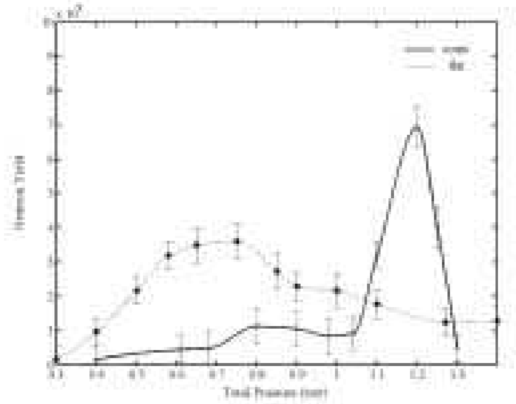

Fig. 3. Variation of neutron yield versus pressure of deuterium + 1% krypton.

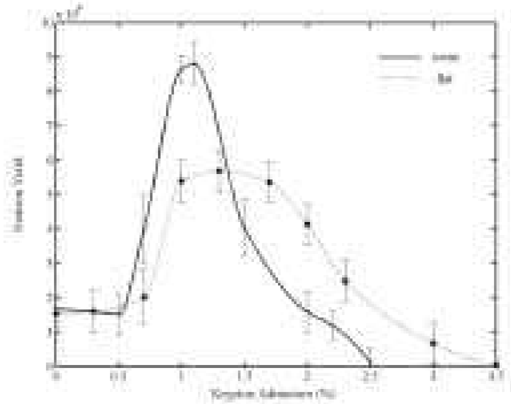

Fig. 4. Neutron yield in two insert anode shapes as a function of krypton percentage.

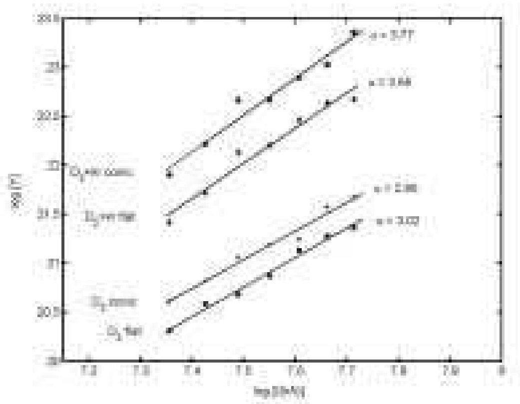

Fig. 5. Neutron yield as a function of discharge voltage in different experiment conditions.

determined for the above conditions. An interesting result has been found that the krypton admixture has an effect of amplifying the thermal mechanism of the neutron production. This argument can be verified by considering the increased values of α in both flat and conic.

References

[1] N.V.Filippov, T.I. Filippova and V.P.Vinogradov, Nucl. Fusion Suppl., Vol. 2, 577,1962.

[2] J. W. Mather, Phys. Fluids Suppl., Vol. 7, pp. 28-34, 1964.

[3] A.R. Babazadeh, M.V. Roshan, S.M. Kiai, et al., Brazilian J. Phys., Vol. 32, March 2002.

[4] A.R. Babazadeh, M.V. Roshan, S.M. Sadat Kiai, Physica Scripta, Vol. 62, 248-251,2002.

[5] H. Herold, A. Jerzykiewicz, M. Sadowski, et al., Nucl. Fusion, Vol. 29, 1255-1269, 1989.

[6] M. Zakaollah, Imtiaz Ahmad, et al., Plasma Sources Sci. Tech., Vol. 5, 544-552, 1996.