Response to "Comment on 'Pinch current limitation effect in plasma focus'" [Appl. Phys. Lett. 94, 076101 (2009)]

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The main point of the comment [Appl. Phys. Lett. **94**, 076101 (2009)] is that Eq. (2) and consequentially Eq. (3) of the commented paper [Appl. Phys. Lett. **92**, 021503 (2008)] require correction. The alternative equation suggested in the comment is derived using Kirchhoff's voltage rule. The comment consider only the energy distribution in the inductive components and the resultant equation confirms a progressive lowering of the $I_{\mathrm{pinch}}/I_{\mathrm{peak}}$ ratio as the static inductance L_0 is reduced, lowering from 0.87 to 0.31 as L_0 is reduced from 100 to 5 nH according to the revised formula corresponding to Eq. (3), compared to 0.63–0.25 according to Eq. (3). This progressive lowering of the ratio $I_{\mathrm{pinch}}/I_{\mathrm{peak}}$ due to the inductive energy distribution is one of two factors responsible for the pinch current limitation. The other factor is the progressive reduction in the *L-C* interaction time compared to the current dip duration denoted by δ_{cap} in Eq. (2). The comment does not deal with δ_{cap} at all; hence, its conclusion based on inductive energy distribution only is not useful, since in the low L_0 region when pinch current limitation begins to manifest, δ_{cap} becomes more and more the dominant factor. In any case, the results of the paper do not depend on Eqs. (2) and (3), which are used in the paper only for illustrative purposes. [DOI: 10.1063/1.3081405]

The paper[1] has one primary point: that for any given capacitance, the pinch current does not increase beyond a certain value however low the static inductance is decreased to. This point is demonstrated by using the Lee model code, which couples the electrical circuit with plasma focus motion, numerically solving these coupled equations point by point through time. All interactions of inductances, capacitance, stray resistance, and motional impedances are taken care of in the code. The formulation of the code is completely consistent with Kirchhoff's voltage and current rules. Equation 2, approximated for brevity, is not used in the code, nor is the further approximated Eq. (3). Their role in the paper is simply to highlight the factors responsible for the pinch current limitation. These factors are now explained as follows:

(a) Lowering L_0 increases I_{peak}, leading necessarily to an increase in "a," hence z_p, hence L_p. The net result is a drop in the fraction $I_{\mathrm{pinch}}/I_{\mathrm{peak}}$.

(b) Lowering L_0 reduces the *L-C* interaction time of the bank while increasing the radial current dip duration. As L_0 is reduced the capacitor bank is more and more coupled to the inductive energy transfer processes. In other words δ_{cap} in Eq. (2) becomes more and more important. I_{pinch} is already reduced by the effect considered in point (a) above, and then δ_{cap} adds in to cause the limitation to I_{pinch} as L_0 is reduced further.

In the paper,[1] Eq. (2) was derived by an inspection of the energy distribution to bring out the two points above. The alternative equation suggested by the comment[2] may be a better representation as far as the inductive components are concerned. However in the low L_0 situations under discussion, this increased accuracy (of *one* of the factors) serves little purpose since the *other* factor of increasing capacitance-coupling (δ_{cap}) is really the dominant factor.

Moreover Eq. (2) serves its purposes to show points (a) and (b) sufficiently clearly. The alternative equations of the comment do not show anything more or new in that respect.

The comment also suggest that keeping the filling pressure constant is "not too reasonable since experimentally changing the filling pressure is far simpler than changing the electrodes geometry and/or the circuit connections." This seems to present the viewpoint of the "hardware" experimentalist. The numerical experimentalist may suggest that the freedom to change any parameter easily makes the numerical experiments more wide-ranging, enabling a greater range of phenomena to be explored. The comment further claim that the "discussed pinch current limitation starts to manifest when the electrodes switches from Mather-type to a Filippov-type and … assumption that $z_p \sim a$ still holds is rather dubious and does not have … experimental support." Contrary to what the comment implies, the regime of current limitation typically starts with electrode parameters still within Mather-type. For example for computations based on the PF1000, current limitation is computed[3] to start as the static inductance is reduced to $L_0 \sim 40$ nH, $z_0 \sim 55$ cm with $a = 15.5$ cm. This is still a Mather-type configuration. Current waveform data[1] of PF1000 show that its static inductance of 33 nH is already low enough to be pinch current limited (i.e., lowering its L_0 further will not increase I_{pinch}). PF1000 has published results[4] of visible and x-ray images

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