A helical magnetic flux compression generator with a conical armature

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Abstract：In this paper the influence of a conical armature on the process of the magnetic flux compression in a simply winded HMFCG is analyzed and simulated systematically by using a two-dimensional magnetic hydrodynamic code MFCG-IV. Simulation results show that output power of an HMFCG with a conical armature can be enhanced, and its pulse length can be reduced.

In the past half century, R&D of HMFCG has been got a great achievement. Although general principles of HMFCG are reasonably well documented, the desire to design an HMFCG with a higher efficiency and versatility，especially with a better matching utility of electrical explosion of wires opening switch(EEOS) is still being remained by most of research groups even now. A two-dimensional magnetic hydrodynamic (MHD) code used to model the dynamic behavior of magnetic flux compression generators with helically wound coils，known as MFCG-IV is developed. In which the Joule heating, Lorentz forces, the flux loss and contact resistance model, a circuit equation to an external load, a model for explosive burn and necessary state equations for some special materials and so on are included[1,2].

1 Physical consideration

As a typical load-limited pulsed power generator, HMFCG's load impedance must be very low for the sake of high output power [3,4]. Therefore usually it is necessary that a power conditioning system such as electro-explosive opening switch (EEOS) is used with an HMFCG in order to get higher output power, the desired high voltage, fast rising wave-front and so on. Meanwhile it is appreciate to make the output current pulse length and its rising wave front as short as possible so as to reduce the design stress in EEOS. There are several ways to limit the pulse length of the output current, for example, experiments on the performance of dual stage HMFCG were carried out[5,6]. Another way to reduce the output current pulse length is to use a conical (tapered) armature (especially to be the second stage segment in a dual stage HMFCG). It is well known that the output energy of an HMFCG will increase if the longitudinal velocity of the dynamic contact point $v_{//}$ increases, while this velocity equals to the detonation velocity for a cylinder armature HMFCG. In a tapered armature HMFCG whose cross-section area increases gradually along the axis, the velocity of the dynamic contact point $v_{//}$ may exceed the detonation velocity considerably, i.e. $v_{//} = D\frac{\sin(\alpha+\gamma)}{\sin(\alpha)}$, where α is the armature's expanding angle, γ is the tilted angle of the conical armature, *D* is the detonation velocity of the HE. Generally the expanding angles for most HMFCG generators are between 9-14 degrees, while tilted angles of the conical armature are most likely less than 5 degrees.

In this paper the influence of a conical armature on the process of the magnetic flux compression in a simply winded HMFCG with a constant pitch is analyzed and simulated systematically by using code MFCG-IV. The basic parameters are selected from a simply winded HMFCG in Texas Tech University [7] mainly.

2 Simulation results

2.1 Comparison between a tapered armature HMFCG and a cylinder armature

The evolution of the magnetic flux compression processes or expanding of armatures (deep yellow color stands for the armatures, while the shallow red dot means the contact point of the detonation wave front with the armature) is shown in Fig.1. The corresponding inductance and resistance evolution of the tapered and cylinder HMFCGs is shown in Fig.2.

From these simulation results it is clear that for the normal cylinder HMFCG, its magnetic flux compression process lasts for about 18.7μs, while for the tapered HMFCG, this process ends at about 16.8μs; since the initial inductance is dependent on the geometry of the HMFCG, the initial inductance of the tapered HMFCG is less than one of the cylinder HMFCG, while both impedances are almost the same before 15μs, where the old impedance and flux loss model version are used in the simulation [8].

2.2 The effects of different tilted angle on output of HMFCG

Using the tapered armature with tilted angles 1,3,5 degrees, respectively, we compared effects of the different tilted angles on the output of tapered armature HMFCGs (the segments of the armatures covered by the stators are tapered) .

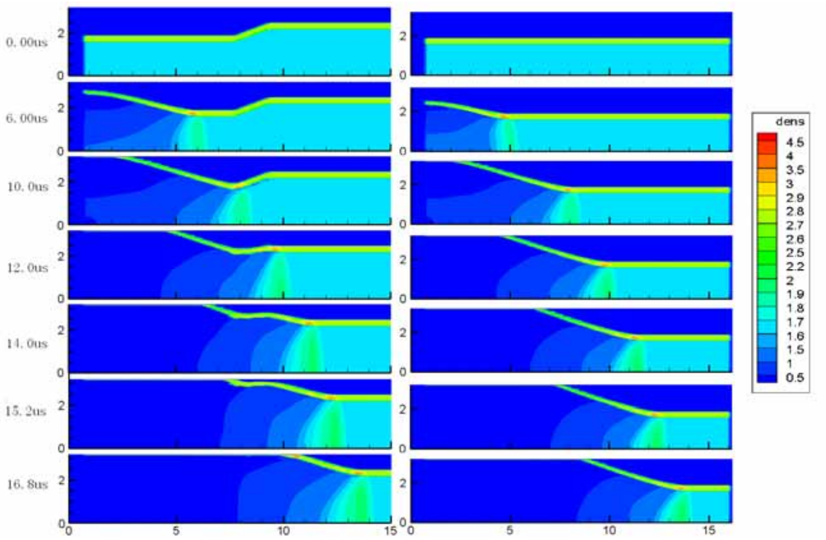

Fig 1 The density evolution of a tapered and cylinder HMFCGs.

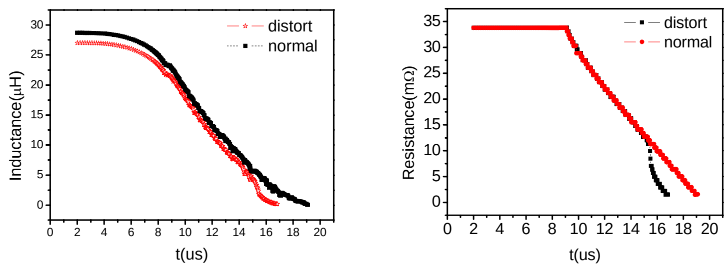

Fig 2 The comparison of inductance and resistance evolution between a tapered and a cylinder HMFCGs

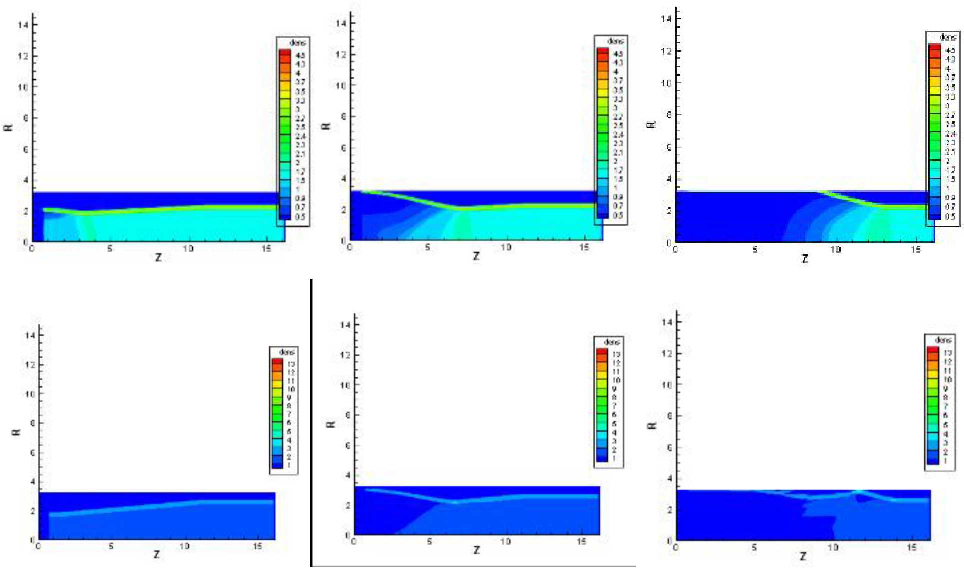

Fig 3 Typical expanding snaps for tilted angles 1, 3, 5 degrees

When the tilted angle is 5 degree, “turn-skipping” phenomenon occurs as shown in the above figure. The evolution of output currents are shown in Fig. 4. There is a shorter pulse length and higher output power in the tapered armature HMFCG with tilted angle 3 degree.

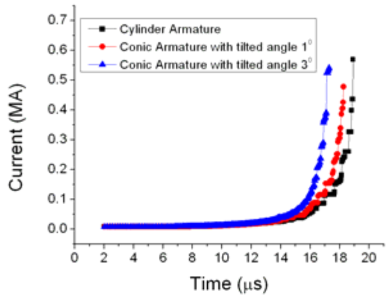

Fig 5 The output currents for tilted armature with the tilted angle 0, 1, 3 degree

3 Conclusions

(1) The output pulse power and length can be adjusted by using tilted armature properly.

(2) Generally the tilted angle of the armature is less than 1/3 of the expanding angle.

(3) The effect on the power enhancement of the tapered armature is not so prominent since the change extension of the tilted angle is quite limited.

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