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Enhancement of the output power in an HMFCG with the fixed wall reflection

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1 Introduction

Helical magnetic flux compression generators (HMFCG) [1] driven by high explosive are widely used in a variety of high-energy and high current applications, especially in a single shot at remote location. General principles of HMFCG are reasonably well documented [2]. Since it is a single shot, self-destroyed device, and its operation deals with quite complex physical processes and mechanisms, HMFCG exist a lot of measurement and diagnosis difficulties. Therefore in order to understand basic physical processes and characteristics of HMFCG and enhance energy exchanging efficiency, an 2D MHD code MFCG-IV is constructed. The Joule heating, Lorentz forces, 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[3,4]. As well known, the performance of high gain HMFCG is dependent on the balance between magnetic pressure and detonation pressure, the detonation pressure is decreased with the expanding of the armature while magnetic pressure is increased. Output energy and current are results of the work done by detonation pressure overcome magnetic pressure. In order to utilize the finite detonation pressure, a “fixed wall” object is placed at rear part of the armature in order to reflect detonation wave before the end of the compression process and to enhance effective detonation pressure. A two-stage flux-trapping HMFCG with cylinder-cone configuration as shown in Fig 1 was simulated. The simulation conditions and results are presented in section two, the conclusion and analyses are summarized in the final section.

2 2D MHD Simulation

An HMFCG model [4] is shown in Fig 1, the first stage (cylinder part with 3 different constant pitches) is mainly used as the energy amplification, and the second stage (cone part) is used to enhance the output power. In the simulation the load inductance and impedance are 4.1μH and 100mΩ, respectively. The final seed current input by a capacitor is 7.65 kA, the detonation velocity and initial density of the high explosive (HE) are 6.2×10^5cm/s and 1.07g/cm^3, with $\gamma = 3$ in the EOS of the HE. Other parameters can be found in the reference [4]. Generally the length of the armature is longer than the length of stator coils, just as Fig.1 shown. In the simulation, it is supposed that a 'fixed wall' object is placed at rear end of the armature, which is 2 or 6 cm away from the end of the stator (i.e. shown in Fig.1, l = 2 or 6 cm). The detonation wave will be reflected from the fixed wall object, while the object will not move within the interested time. For this set of parameters, $l \geq$ 10cm almost means that reflected detonation waves have no effects on the magnetic flux compression process.

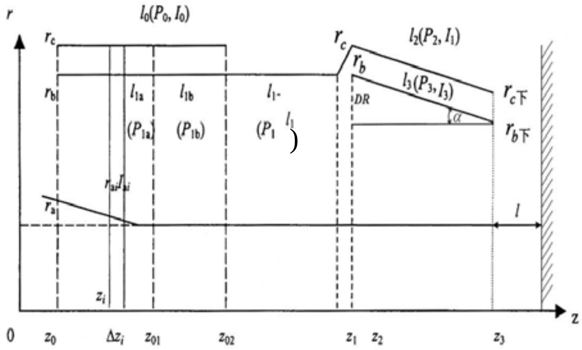

Fig.1 Sketch of a two-stage flux trapping HMFCG of the Cylinder-cone configuration

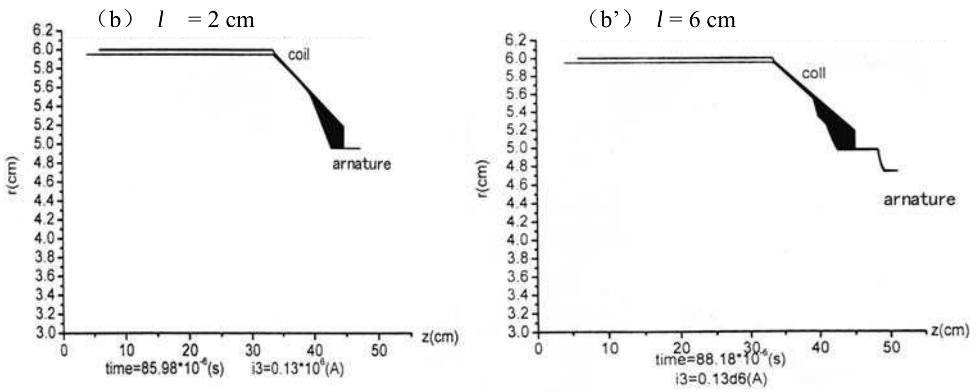

Fig. 2 The impact trajectories between the armature and the stator coil for l = 2 cm and 6 cm. (a) t = 85.98μs and (a') t = 88.18μs with the output currents are same I = 130 kA.

The black shadow areas in Fig.2 are un-compressed spaces between the stator and the expanding armature. In the simulation operation of the second stage (cone part) starts at t =

72.5μs. Fixed wall objects are placed at the position of 2 cm and 6 cm from the rear end of stator coil, respectively (l = 2, and 6cm), both HMFCG can output currents of 130kA, but at different time: for (a) case, t = 85.98μs while for (a') case t = 88.18μs, that means the power $\frac{dW_H}{dt}$ and the peak voltage $L_H \frac{dI_H}{dt}$ output to load of case (a) is larger than the in case (a').

2.1 Velocity of a special point on the armature outer surface

Evolutions of expanding velocities of the special point from the rear end of the stator coil 5cm axially are shown in Fig.3. From this figure, it is found that at the beginning of the magnetic flux compression procedure detonation pressure was much larger than magnetic pressure, so expanding velocity of the armature increased quite rapidly to peak value of about 1.2km/s, then with the compression (and the current enhanced) process magnetic pressure increased and gradually magnetic pressure was comparable with the detonation pressure or even overcome it, so the expanding velocity decreased. If a 'fixed wall' object is placed at the proper position the reflected detonation wave will greatly increase the radial expanding detonation pressure, so the expanding velocity or detonation pressure will increase which will make the output current and power enhance.

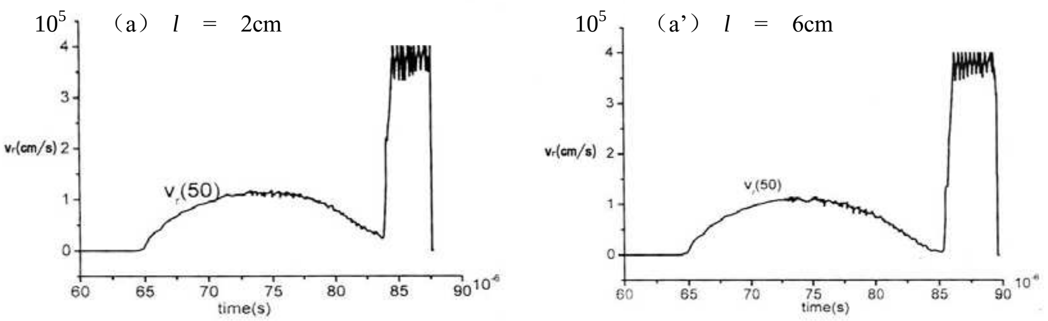

Fig.3 Evolution of the armature radial velocities at the special axial position of the armature's outer surface for case (a) l = 2 cm and case (a') l = 6 cm.

2.3 Evolution of the output current

Evolutions of load currents for different fixed wall object positions are shown in Fig.4. The reflected detonation pressure is quite useful to enhance load current or decrease the operation time, so both of the power $\frac{dW_H}{dt}$ and peak voltage $L_H \frac{dI_H}{dt}$ output to load of case

(a) is larger than case (a') at the same time.

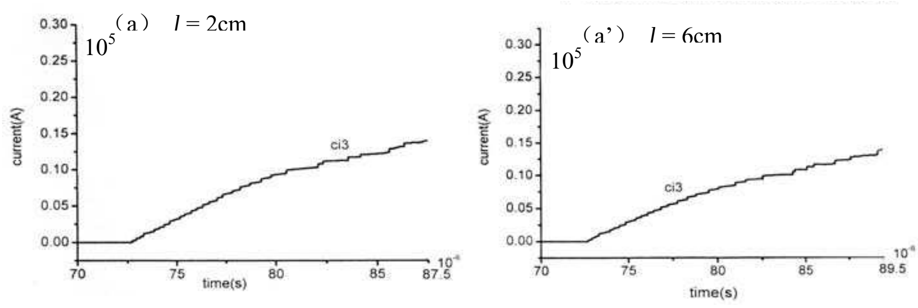

Fig 4 Evolution of the load currents（a）l = 2cm，(a') l = 6cm.

3 Conclusion

MHD simulation results show that on the second stage of a two-stage flux trapping HMFCG, magnetic pressure is comparable to detonation pressure, the effect of magnetic pressure becomes the main factors which limit current enlargement. It is concluded from the simulation that by choosing a proper fixed wall object placed at an appropriate position at real end of the armature to reflect detonation pressure, the effective detonation pressure are enhanced, generally output power and its time variation of current in an HMFCG can be enhanced by the fixed wall object reflection.

References

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