EXPERIMENTAL STUDY OF THE MULTIGAP MULTICHANNEL GAS SPARK CLOSING SWITCH

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Abstract

A coaxial multi-gap multi-channel gas spark switch with stainless steel spring ring gap electrodes is investigated. The switch is triggered by a pulse applied to the cylindrical electrode outside the discharging channel through parasitic capacitance coupling. The jitter of the switch is reduced by several short distance gas gaps in series, and its inductance is reduced by multi-channel discharge on account of the inductor isolation between the coils of the spring ring electrode. The experimental results indicate that the switch is of low inductance (15～30nH), low jitter (～3ns), and stable breakdown performance.

1 INTRODUCTION

High voltage and current closing switch is one of the key elements in pulsed power systems. With the development of pulsed X-ray simulator and high power Z-pinch technology recently [1], it is required that the closing switch is of small inductance, low jitter, high conducting current and long operating life.

One of the methods to reduce the switch inductance, the jitter and the electrode erosion in conducting high current for increasing its reliability and longevity is to adopt many gaps in series and to form multi-channel discharge, so the multi-gap multi-channel spark closing switch is investigated at home and abroad [2-4]. The coaxial multi-gap multi-channel closing switch is designed. This paper presents the structure, the trigger principal, the experimental setup and primary experimental results of the breakdown characteristics of the switch.

2 THE STRUCTURE OF THE SWITCH

The configuration of the coaxial multi-gap multi-channel switch is showed in figure 1. The cylindrical trigger electrode is isolated from the discharging channel by a Nylon insulator. The total discharging gap is composed of five short gaps in series, the high voltage metal membrane resisters between the gaps make them have equal voltage when the capacitor is charged, the middle gap electrodes are made of a stainless steel spring whose diameter and the distance between the adjacent screw thread are 16mm and 5mm, respectively, and the diameter of the high voltage circular electrode is 162mm. The chamber is filled with 0.3 MPa N_2 gas.

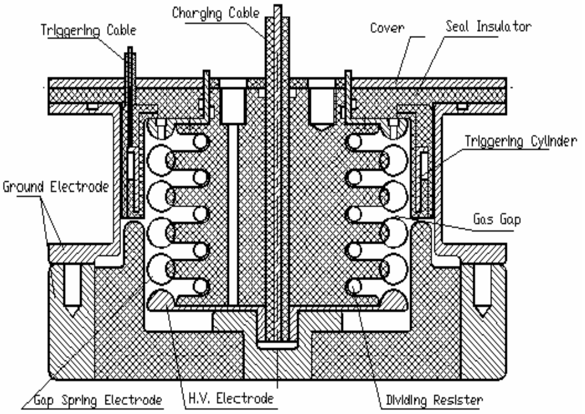

Fig.1 Structure of the MMCS

The electric field distribution of all gaps of the switch is symmetric at the moment of the capacitor charging, while the electric field distribution of the gaps adjacent to high voltage electrode and ground electrode is increased remarkably, and that of the middle gaps is not varied evidently at the arrival of the trigger pulse.

3 THE TRIGGERING PRINCIPALE

The equivalent circuit of the experimental setup in considering the parasitical parameters of the switch is presented in figure 2. C_0 is a 0.7μF capacitor with the equivalent inductance of 30nH. The symbols of L and R stand for the equivalent inductance and resistance respectively. C_1, C_2 and C_3 are the parasitical capacitors between the gap electrodes, the trigger electrode and the ground electrode. According to the practical size of the switch, the parameters are as followed: $C_1 \approx 25pF$， $C_2 \approx 720pF$， $C_3 \approx 5pF$. When the capacitor C_0 is charged, the voltage of every gap is similar and the polarity of the trigger electrode is of the same as that of the capacitor C_0 on account of the parasitical capacitors coupling. When the negative polarity trigger pulse is applied, the local electric field between the gaps is distorted violently, giving rise to multi-channel discharge and breakdown of the switch.

The simulation for the various gap voltage is conducted through the PSPICE program with the applying trigger pulse being –100V and the rise time of 30ns. The simulation results are showed in figure 3, which indicate that the voltage of the up and bottom gap is varied from 20V to 80V, and that of the middle gaps basically doesn't change. The up and bottom gap of the switch is more susceptible to breakdown, particularly for the bottom gap which is adjacent to high voltage electrode. This is in consistent with the calculated electric field distribution of the gaps at the trigger moment by the SUPPERFISH program.

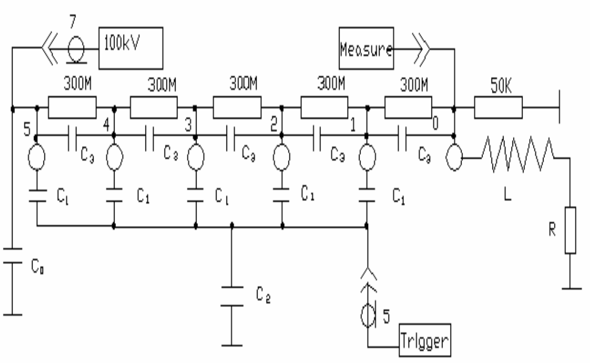

Fig.2 Equivalent circuit of MMCS

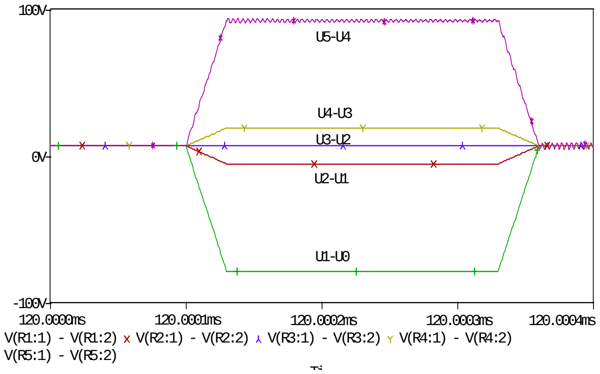

Fig.3 The voltage distribution of the five switch gaps under trigger pulse

4 THE PROPERTIES OF THE SWITCH

4.1 The self-breakdown voltage

The experimental relationship curve of the self-breakdown voltage of MMCS verse the absolute N_2 pressure in the chamber is plotted in figure 4. The self-breakdown voltage of MMCS increases linearly with the pressure, and the jitters of the self-breakdown voltage of MMCS of 0.15, 0.225 and 0.25 MPa are greater than that of other pressures.

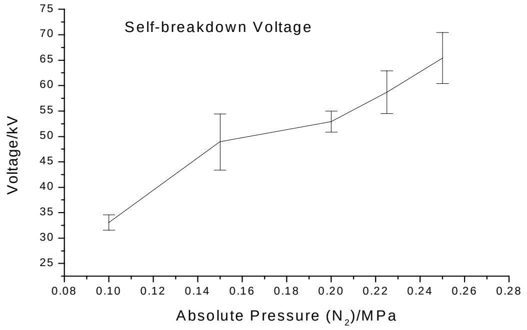

Fig.4 The self-breakdown voltage vs pressure

4.2 The trigger-breakdown characteristics

When the charging voltage of the capacitor C_0 and the trigger pulse keep unchangeable, the trigger-breakdown characteristics of MMCS verse the absolute N_2 pressure are obtained by utilizing the methods in reference 5 according to the discharge current waveform, such as the equivalent circuit inductance, resistance, peak current, and the moment of peak current. Figure 5 is the experimental curve of the breakdown delay of the switch and equivalent inductance of the circuit verse the gas pressure. Excluding the inductance of the capacitor C_0 and the electrode connection ～45nH, the inductance of MMCS is in the range of 15～30 nH. With the pressure increasing, the inductance and jitter of MMCS increase slightly. Figure 6 is the curve of the peak current value and the quart periods verse the pressure, the peak current value and time varies from 160kA to 180kA and from 300ns to 340ns respectively when the gas pressure scales from 0.3MPa to 0.4MPa. With the pressure increases, the peak current time increases slightly, while the peak current value decreases slightly. Figure 7 is the experimental curve of the equivalent resistance of the circuit verse the gas pressure, the equivalent impedance of the circuit increases as the pressure increases from 0.3MPa to 0.38 MPa, but this is not true for 0.4MPa.

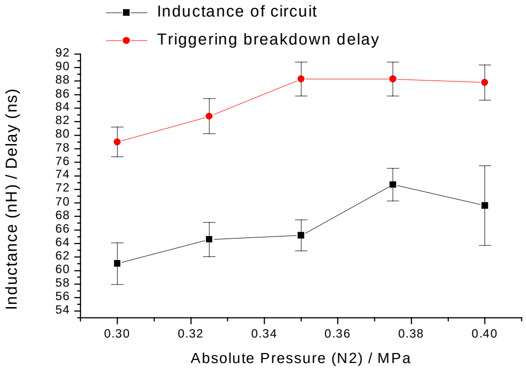

Fig.5 the trigger breakdown delay and inductance of MMCS vs absolute pressure

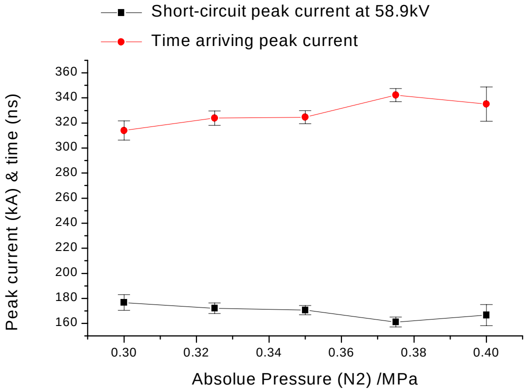

Fig.6 the curve of peak current & time vs pressur

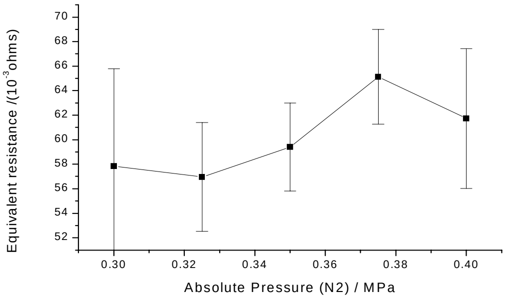

Fig.7 the equivalent resistance vs pressure

5 CONCLUSION

The trigger method based on the parasitical capacitor coupling is valid and reliable when the trigger electrode is outside the discharging channel. This approach is capable of reducing the switch operating jitter on account of the electrode erosions. The inductance, jitter and electrode erosions of the switch are reduced due to the use of many short gaps in series and stainless steel spring between the middle gaps to form multi-channel discharge. The primary experimental results indicate that the coaxial multi-gap multi-channel closing switch is of low inductance (30 to 15 nH), small jitter (3 ns), and stable breakdown performance.

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