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Research on 100kJ pulsed power module for electromagnetic launch

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Abstract: With the development of the electromagnetic launch (EML) technology, the requirement of the pulsed power supply is increasing. Capacitor-based pulsed power supply usually consists of several hundred kilojoule level pulsed power modules (PPM) in parallel. The PPM for EML system requires the capability of continuous working ability, high energy storage density and high peak current. A 100kJ compact PPM with rated operational voltage 10kV was designed, the output peak current was about 90kA, and the continuous working ability was 6 times per minute. The design and selection of main components in the module were simulated. At last, the PPM was used in the testing of the coil gun. It provides transient pulse current test platform and technical support for the subsequent construction of megajoule level pulsed power supply.

I. Introduction

Pulsed power supply (PPS) is an important part of electromagnetic launch (EML) system, which provides the required power for emission. It can be used in electromagnetic rail gun, electromagnetic coil gun and electrothermal-chemical gun. In order to meet the demands of launch frequency and installation space in EML system, the PPS designed for EML system must have compact structure and rapid energy storage. The capacitive PPS, one of the best power supply forms for EML system, has the advantage of quick charging and being suitable for modular integration.

In this paper, a 100kJ compact PPM with rated operational voltage 10kV was designed, the output peak current was about 90kA, and the continuous working ability was 6 times per minute. The thermal simulation of the design and selection of main components in the module was carried out. The PPM was used as a transient pulse current testing platform for the coil performance testing of the coil gun.

II. PPM and Components

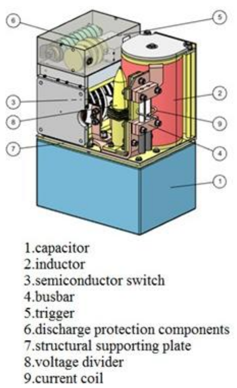

Figure 1 Structure of the PPM

The structure of the PPM shows in Figure 1. The locations of major components and related test equipment are marked in the figure. In order to integrate the PPM, we need to overcome some difficulties, such as electrodynamicforce, temperature rise, electrical contact and electric insulating. In order to effectively improved the integration of PPM.

We took a series of technical measures as follow: (1) Integrated package of the pulse thyristor and crowbar diode makes the semiconductor structure optimized. (2) According to the shape and structure of the semiconductor switch, the structure of the energy storage capacitor and pulse-shaping inductor were optimized and adjusted. The PPM dimension is 470mm×330mm×640mm and the energy storage density is about 1MJ/m^3.

III. Thermal Simulation

Figure 2 shows the current density distribution of the inductor. Because of the transient skin effect and proximity effect, the current distribution of the copper belt is very uneven. The current mainly concentrates on the inner surface of the copper belt, while the current density on the outer surface is relatively small. At the 0.4ms, the maximum current density is 4.43x10^{9}A/m^2.

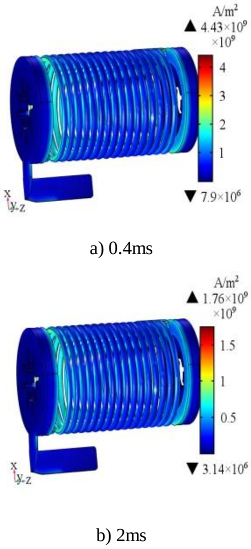

Figure 2 Current density distribution of inductor

Figure 3 shows the current density distribution of the inductor. Because of the transient skin effect and proximity effect, the current distribution of the copper belt is very uneven. The current mainly concentrates on the inner surface of the copper belt, while the current density on the outer surface is relatively small. At the 0.4ms, the maximum current density is 4.43x10^{9}A/m^2. In the process of discharge, the temperature distribution of the copper strip is extremely uneven due to the skin effect of current. In the discharge gap, because of the good thermal conductivity of copper, the temperature of the copper strip drops rapidly. In the whole process, the highest temperature of the copper strip is no more than 350K.

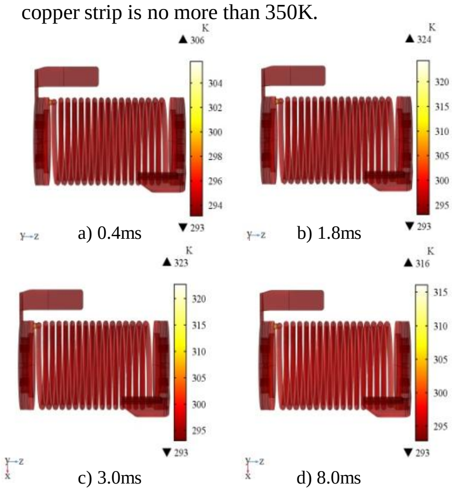

Figure 3 Temperature distribution of inductor

IV. Coil Performance Test

The 100kJ PPM is a transient pulse current test platform, which can be used for coil performance test. The coil was tested for 1-5kV discharge performance to verify the reliability of the coil design. Figure 4 shows the charging voltage waveform of 5kV under similar half-power mode of the capacitor charging power supply, which takes about 5.5s. Figure 5 shows the 5kV discharge current waveform, and the current peak value is about 19.45kA. The experimental results were intact, the coil structure was not damaged, and the measured electrical parameters were not different from the measured values before the experiment, which verified the design rationality of the coil. It provided technical support for subsequent coil gun design.

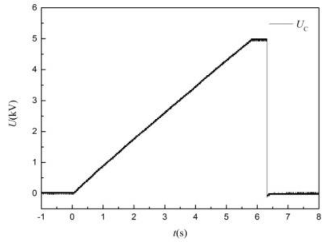

Figure 4 The voltage waveform charging 5kV

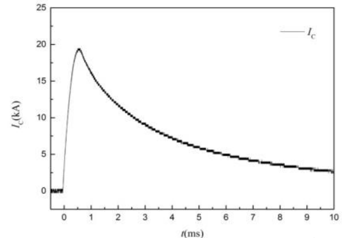

Figure 5 The 5kV experimental current waveform of coil

V. Conclusion

Based on the topology of capacitor energy storage pulsed power supply, a 100kJ PPM with compact structure and continuous working capacity was designed in this paper. Rapid heat accumulation of continuous discharge operating conditions, which reduces the reliability of the situation, has carried on the thermal simulation. The PPM with energy storage density of about 1MJ/m^3, has the ability of continuous short-time work. The constructed PPM was applied to test the performance of a coaxial coil which is used for subsequent electromagnetic propulsion. The following research work will be carried out.

1. Test the continuous discharge performance of the power module at the rated voltage.
2. Most of the simulation calculations are under ideal conditions, so it is necessary to further improve the simulation computing capacity.
3. Develop coils that can withstand higher discharge voltage.