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Acoustic Effects of Underwater Plasma Pulsed Sound Source under Different Electrical Parameters

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Acoustic Effects of Underwater Plasma Pulsed Sound Source under Different Electrical Parameters

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Abstract: Methods of pulse discharge in water were studied under different voltage and conductivity parameters. The voltage and current data in the experiment were collected and analyzed. Then the mechanism of the two discharge modes was briefly discussed (the initial mechanism of the corona mode is still unclear compared to the thermal process mechanism of the arc mode). Finally, two kinds of discharge methods were compared and analyzed from the aspects of experimental phenomena, production mechanism and application prospects. The experiment found that the acoustic effect of corona discharge in water under large solution conductivity is obvious, which provides a new idea for the design of underwater plasma sound source.

1.Introduction

The pulsed arc discharge in water can generate high-energy plasma channels that expand outward from the internal high voltage in an instant, and achieve high-speed conversion of electrical energy to mechanical energy by the weak compressibility of the aqueous medium. It was widely used in industrial fields since the Soviet Union began systematic research in the 1950s, such as medical extracorporeal lithotripsy, hydroforming in machining, underwater acoustics and plasma sound sources in seismic exploration, and the environment. Water treatment is in the project and rock fragmentation is in geotechnical engineering. The Institute's series of underwater plasma sound sources (ie. spark source) from the late 1980s have also achieved many important results. Arc discharges that previously formed plasma channels underwater have lower acoustic efficiency, electrode materials have faster corrosion rates, and sound sources generate multiple pressure waves when excited in free-field waters (only the first one is effective for seismic exploration, and other subsequent pressures.The wave will interfere with the recorded results). The above defects can be eliminated by the post-processing of the records, but the cost is high and can only be solved from the sound source itself. A discharge form in which the arc-free channel is turned on, so-called "corona discharge", can also produce a strong acoustic pulse in a slightly lower voltage level, higher conductivity brine. However, this complete liquid phase corona discharge is clearly distinguished from the DC corona discharge in the gas phase and gas-liquid two phases in terms of experimental parameters, phenomena and results.

At present, there are many reports on underwater arc discharge in water and water corona discharge in water treatment (in sewage or gas-liquid two-phase), but for single liquid medium, suitable for underwater plasma sound source. The pulse corona discharge under the parameter conditions, as well as the similarities and differences between the arc and corona discharge modes, the related experimental and theoretical results are rarely found in the literature. In this paper, the results of voltage and current waveforms of discharge loops in pulsed discharge experiments under different parameters are given. Two underwater pulse discharge patterns are compared, analyzed and discussed. Finally, suggestions and ideas are summarized.

2.Basic theoretical analysis

The ocean is an important part of the Earth's ecological environment, accounting for about 71% of the Earth's surface area. In recent years, with the development of marine resources and the development of information technology, the feature analysis and recognition technology of underwater sound sources has gradually become a research hotspot, which is widely used in navigation orientation of acoustic equipment, remote control and monitoring of underwater equipment, underwater mammal detection and identification, emergency communications and other aspects. In addition to the rich resources, the ocean is also a very important life carrier on the earth, and many marine organisms born here are also an important part of the ecosystem. About 210,000 marine organisms are currently known, and marine organisms provide humans with a large number of food sources and other resources, which are of great developmental value. In the process of developing marine organisms, effectively studying the characteristics of various types of marine resources is the premise of protecting marine organisms, and provides a prerequisite for effectively identifying submarine target categories and sensing other state information. This paper mainly studies the feature analysis, type identification and state perception of underwater sound sources, which are also of great value in marine exploration and marine biological protection.

The electroacoustic conversion model of the underwater plasma pulse sound source is mainly composed of a charging circuit, a discharging circuit, a discharge vessel and a measuring system. The discharge capacitor is disconnected from the charging circuit after being charged to the desired voltage. The gas spark gap switch controlled by the manual trigger module is turned on, and the discharge circuit is closed. A resistor divider connected in parallel across the discharge electrode measures the discharge voltage waveform, and the series coaxial shunt measures the loop current waveform. The discharge electrode is made of a coaxial cable. The part that is not in the water is naturally insulated by the outer sheath of the cable and is connected to the copper electrode only at the end. The "needle-to-pole" electrode spacing is adjustable to accommodate different forms of discharge. The discharge vessel is equipped with a water circulation system to avoid contamination of the water in the container by factors such as discharge. It is obvious that the breakdown process of the discharge is μs level, but the pre-breakdown process is ms level. This is related to the lower voltage level used in the experiment (to compare the mechanism of the two discharge methods), and is different from the previous large number of ns, μs water pulse discharge experiments.

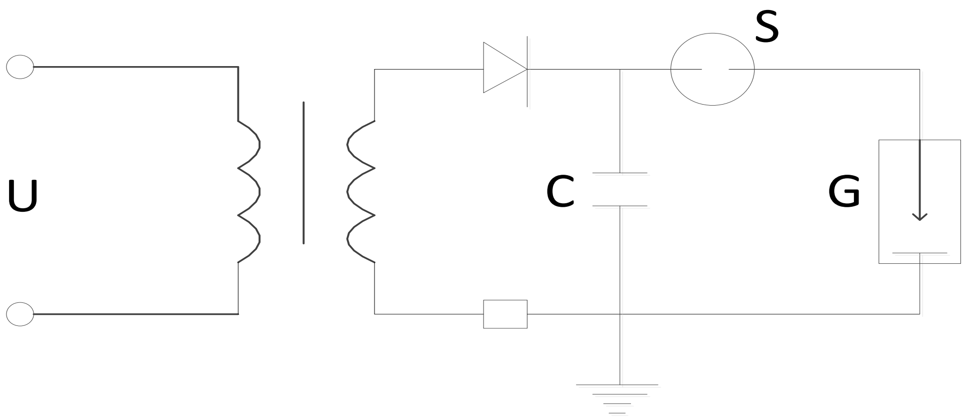

Figure.1 System schematic

3.Electro-acoustic Conversion Characteristics of UPPSS

The main breakdown mechanism of water at low field breakdown is the heating and gasification of water caused by ion conduction current. Comparison of theoretical and experimental values of the relationship between ρ and breakdown delay under parameter conditions (low field strength). It can be seen that the theoretical value is in good agreement with the experimental value when ρ is high, and slightly different when ρ is low. In short, the pre-breakdown time is roughly inversely proportional to ρ, so it is basically considered that the main mechanism of water medium breakdown under these conditions is heat process. This is basically consistent with the current thermal model view in the study of high field strength, μs or sub-μs water medium breakdown mechanism.

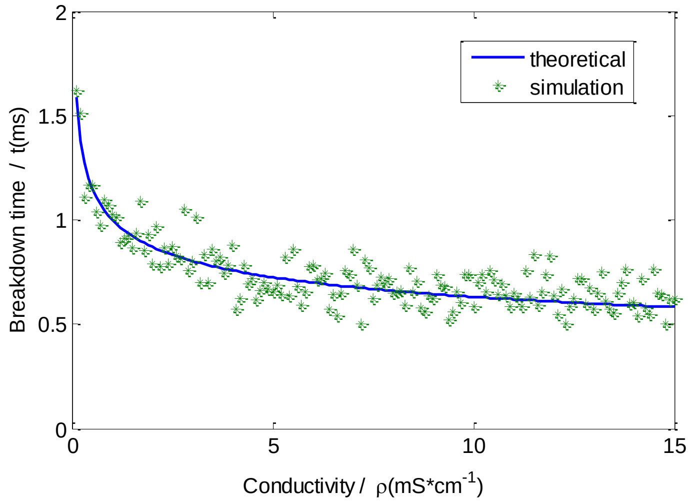

Figure 2. Calculated results and simulation data of solution conductivity to breakdown delay time

The waveforms of the four different ρ subpulse corona discharge currents are shown in Fig3. A similar phenomenon was previously discovered during the experiment, but it has not been studied in depth. This pulse corona discharge can only occur when d is large. The discharge waveform is basically independent of the d size. The waveform obtained when d=250 mm is basically the same as the waveform obtained when d is larger. 3 As the ρ increases, the current peak increases and the peak time advances. 4 This pulse corona discharge is difficult to occur when ρ is too low, but can be observed under the parameter condition and ρ = 2 mS/cm, and is more obvious when ρ = 5 mS/cm. When ρ is larger, the acoustic effect is more obvious, and the electroacoustic conversion efficiency is higher, and the amplitude of the acoustic pulse pressure wave at this time can be compared with the amplitude of the main pressure pulse wave formed by the pulse arc discharge mode under the same condition.

It can be seen from Fig. 3 that i and ρ are basically linear, so the pulse corona discharge can be equivalent to a resistance (determined by ρ) model from the circuit, but the microscopic process is still unclear. Completely vented by a coronal corona discharge, there is no conductive plasma channel, so it is obviously not directly explained by the "thermal model". Typical pulse corona discharge current, voltage and power dissipation curves. It can be seen that the discharge efficiency of corona mode is significantly higher than that of arc mode. In the experiment, a spherical plasma ball is generated at the electrode, accompanied by obvious acoustic pulse and bubble process, which is beneficial to design a low field strength condition. The new underwater plasma sound source. In addition, changing the electrode structure allows the two electrodes to be discharged simultaneously or separately. It is worth mentioning that in the experiment, it is found that most of the discharges have a significant secondary discharge process at a higher ρ (about 50 mS/cm), and the microscopic mechanism needs further experimental analysis.

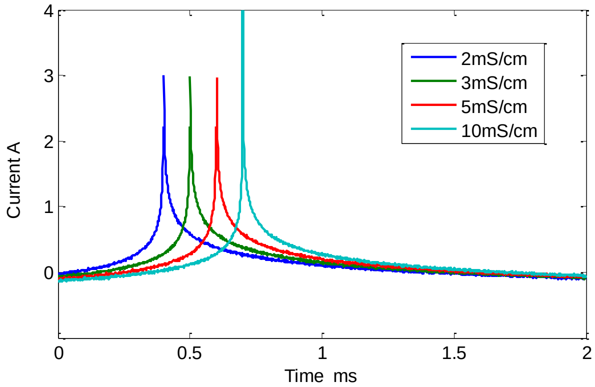

Figure.3 Current oscillations of the pulsed discharge under different solution conductivities

The above experimental study on the two methods of pulse discharge in water (arc discharge and corona discharge) under the same experimental facilities and environmental parameters found that the experimental phenomena and process mechanisms of the two are quite different. The former forms a distinct plasma channel, while the latter does not. Only the plasma balls of the coronal corona are formed at both ends of the electrode. The former is only generated when the electrode distance d is small and is sensitive to d, the latter occurs when d is large, and the discharge process is substantially independent of d when d is sufficiently large. The former can be better explained by the current popular thermal process model, while the latter can be equivalently equivalent to the resistance model, but the microscopic mechanism is still unclear and cannot be explained by the "thermal model". The latter can generate a strong acoustic pulse at a higher ρ, and its pressure wave amplitude can be compared with the pressure wave main pulse amplitude formed by the former under the same experimental parameters. The underwater sound source based on the latter is obviously superior to the former based on the former: it can achieve similar acoustic effects by expanding into a multi-electrode configuration, vocalization and sound intensity can be controlled, electrode corrosion is significantly slowed, electroacoustic conversion The efficiency is increased, the required applied voltage is small, and the charge and discharge circuit can be compacted by modern power electronics technology, which is beneficial to design a new underwater plasma sound source in a low field environment.

4.Conclusion

After methods of pulse discharge in water under different voltage and conductivity parameters were studied, two kinds of discharge methods are compared and analyzed from the aspects of experimental phenomena, production mechanism and application prospects. The experiment found that the acoustic effect of corona discharge in water under large solution conductivity is obvious, which provides a new idea for the design of underwater plasma sound source.

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