Experimental and numerical study of a bubble plasma gas initiated by a wire explosion in a liquid

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Applications, using electrical arc in liquid, increase with the use of pulsed energy of microseconds or nanoseconds. Some observed phenomena are common to those applications like the presence of a gas bubble surrounding the discharge. In order to understand the different mechanisms driving the bubble behavior, a numerical and an experimentation studies with a longer pulse of energy around 10ms were developed. The experimental results show an expansion and then a collapse of this bubble during the discharge. These observations linked to simulation results suggest some similitudes with the literature, such as the heating of the liquid and the gas by the discharge and a rise of pressure during the expansion of the bubble.

1. Overviews

Electrical arcs in liquids have many applications such as electrohydraulic discharges in water [1], nanostructures synthesis in various aqueous solutions [2] or oil circuit breakers [3]. Although the conditions on time and energy discharges are different for each of those applications, a gas bubble surrounds the arc. The aim of this work is to understand the mechanisms and phenomena driving the gas bubble with experimental and numerical approaches.

The experimental setup is composed of an electrical alimentation, a reactor and measurements. The electrical alimentation enables to generate a 10ms pulse current of a few kA. The reactor contains two tungsten plane electrodes of 1.6mm diameter immersed in the liquid. The area between the two electrodes is observed by a fast camera. In the same time, the electric discharge characteristics are measured by current and voltage probes.

A numerical model is also proposed to support the experimental results. The Fluent ANSYS software is chosen [4]. The VOF (Volume-Of-Fluids) model is adopted and completed with the change phase Lee's model [4].

2. Study cases

The experimental setup allows to change some parameters such as the inter-contact gap, the injected energy and power or the liquid environment. For example, a case in water liquid can be studied with a distance between the two electrodes of 3mm initially linked by a copper fuse wire of 100µm. The delivered energy for the electrical arc is 1kJ during 10ms. As other author observations [1-3][5], a gas bubble containing the electrical arc is observed. The simulation results show a global rise of the temperature as in Burakov et al. work [2] due to Joule effect and of the pressure as in Chen et al. work [1]. In our theoretical case, the central temperature and pressure can reach respectively 16kK and 15bars inside the bubble. Consequently, these characteristics lead to the bubble expand. When the injected energy is not sufficient, the gas is cooled and the pressure decreases. So after one phase of expansion, the bubble quickly collapses. This dynamic is also noted by others authors using different experimental conditions [3] like a shorter time of discharge [5].

3. Conclusions - Perspectives

An experimental setup and a theoretical model are developed to study the plasma bubble behavior in a liquid. In order to be able to discuss the bubble dynamic a parametric study is made changing the distance between the two electrodes, the nature of the liquid, the apply energy. All these results will be presented and discussed.

4. References

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