MECHANICAL FORCES IN INSULATING LIQUIDS SUBJECTED TO HIGH ELECTRICAL FIELDS

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ABSTRACT

The thesis presents an experimental investigation of the forces and pressures acting on an air bubble injected in transformer oil, under different test conditions. The gap configuration consisted of a sphere-plane electrode system, the sphere had a diameter of 11.2 mm and the circular plane had a diameter of 30 mm. The sphere electrode was drilled along a diameter, and by the novel test cell used it was possible to inject a controlled air bubble in the liquid at the surface of the sphere electrode.

The test cell and experimental technique was suitably designed to measure the internal pressure of the air bubble, and hydrostatic pressure above it. The values of internal pressure P_i and the hydrostatic pressure P_h were recorded under different test conditions. The effects of hydrostatic pressure, applied voltage and gap setting were studied for both alternating and direct applied voltages of different polarities.

A family of relationships between the internal pressure of the bubble and the hydrostatic pressure at different applied voltage were obtained for five gap settings, under A.C. and D.C. reverse polarity voltages.

the square of applied field E^2 at low field regions (before corona inception inside air bubble) i.e. at both "Region I" and "Region II". However the slope of $P_e - E^2$ relation at "Region I" is higher than that of "Region II".

Results show that P_e increases non linearly with E^2 after corona inception i.e. at "Region III".

The electric pressure equations are obtained from the $P_e - E^2$ linear relations at "Region I" and "Region II" for the five tested gaps.

The effect of gap configuration (L/r) i.e. (gap distance/sphere radiues) on the electric pressure are obtained. The equations of electric pressure for gap configuration (L/r) tends to zero (i.e. field approaches to a uniform field) are deduced, these equations are similar to those previously obtained by mere theoretical considerations. Also the electric pressure equations show that there is a critical gap configuration L/r at which the electric pressure changes its direction from positive to negative values. These critical gap configurations L/r have values ranging from 5 to 7.

It is suggested that the transition from one region to another is a pressure dependent phenomenon The third region in the $P_e - E^2$ characteristics is believed to start after corona inception inside air bubble. The pearl-like stream phenomena, observed in present experiment, may be attributed to a high negative electric pressure. This negative electric pressure occurs for gap configurations higher than a certain critical value, this critical gap configuration is that at which the electric pressure is equal to zero.

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CHAPTER 1

INTRODUCTION

It is well known that the application of a high electric field to a liquid dielectric creates an internal pressure. Evaluation of the induced electrical pressure in insulating liquids has been largely based on theoretical assumptions and mathematical derivations which have been at variance. The net induced electrical pressure could be the resultant of a number of electrically induced pressures, e.g. electrostatic, electrostrictive, dielectrophoretic, electrophoretic ... etc. The problem is further complicated since some of these electrically induced pressures may assist or oppose each other, depending on the prevaling test conditions.

The present work was carried out with the following objectives:

a. Construction of a test cell suitable for measuring these forces.

b. Design an injection system to inject a controlled air bubble at a sphere electrode surface. This air bubble is the point of measuring all generated forces on it at different test conditions.

Chapter 2 gives a review of previous work, which has a direct bearing on the present thesis. This chapter includes the early history of the subject, the theory of force generation in liquid dielectrics. The action of electrophoretic and dielectrophoretic forces, with dielectric and cluster formation is discussed.

Chapter 3 is concerned with the description of the experimental apparatus and test procedures. A novel feature of the present work is the use of a new test cell by which it was possible to measure the internal pressure of a controllable injected air bubble. Alternating applied voltages (50 Hz), and direct applied voltages with reverse polarity up to 30 kV are used.

Chapter 4 presents the obtained experimental results. Section 4.2 is concerned with the preliminary experiments. Section 4.3 gives results of the internal pressure of air bubble under different test conditions. Section 4.4 is concerned with the study of the applied forces on air bubble liquid boundary at sphere electrode surface.

Results of electric pressure in transformer oil under different test conditions are given in section

4.5. Section 4.6 is concerned with the effect of applied voltage on surface tension pressure of air bubble. The variation of hydrostatic pressure drop required for air bubble ejection with the square of applied voltage is given in section 4.7. Section 4.8 is concerned with the variation of surface tension pressure change of air bubble from starting till ejection, with gap distance.

Chapter 5 gives the analysis and discussion of test results.

The main results are analysed and discussed with an attempt to explain the observed phenomena during experimental work.

To the author's best knowledge, the following aspects of the present work are new:

1. The novelty of the test cell and test apparatus which enabled the measurement of internal pressure of injected air bubble.

2. The experimental verification of the electric pressure equation in insulating liquids.

3. The critical gap configuration (L/R) i.e. gap distance/sphere radius at which the electric pressure

changes it's direction from positive to negative is found to be within the range 5 to 7.

4. Results indicate that the air bubble is changed from a non-conducting to a conducting state after corona inception inside it. This means that the gap configuration is changed from sphere-plane to a needle-plane configuration which leads to very high electric fields under moderate applied voltages. This high field may be sufficient for initiating air bubbles in the insulating liquid. Bubbles of Pearl-Like stream appearance phenomena were noticed during the experimental work.

5. The newly developed test apparatus may be used in determing the surface tension of liquids. The surface tension for an air bubble in transformer oil is calculated and found to be 42.7 dyne/cm.