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PARTIAL DISCHARGES IN NATURAL GASEOUS VOIDS IN EPOXY INSULATION

1. Introduction

The paper presents results of investigations of partial discharges (p.d.)intensity in spherical gaseous voids in epoxy insulation - in voids formed in the process of casting.

Progress in the process engineering of casting and impregnation of insulating systems with application of epoxy resin manifests itself, among others, in decrease of quantity and dimensions of gaseous voids.

Described investigations are continuation of the earlier investigations made by the author [1] using samples of epoxy insulation containing natural spherical voids with the diameter larger than 1 mm. At present stage epoxy resin samples with natural voids which diameters are smaller than 1 mm were being investigated.

Estimation of relation between p.d. intensity represented by a maximum apparent charge and a gaseous void volume is the main aim of these investigations. The practical importance of results of such investigations is connected with wider and wider introducing of p. d. intensity measurements as the product tests, for instance of measuring transformers [2,3]. The knowledge of p. d. intensity dependence on gaseous void volume would give the chance of estimation of defect largeness in the insulation of ready-made high voltage devices.

2. Samples of epoxy insulation with natural voids

The use of fillers is the substantial obstacle in testing of a resinous insulation, for instance of measuring transformers, and makes the measurement of void largeness impossible. Therefore it was determined to

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take for testing of cured epoxy resin pieces (Epidian 5, curing agent Z1) with voids formed in natural way in casting and curing process.

For the purpose of obtaining voids as approximate to these which are in the insulation of practical insulating systems as possible the mixture of the resin and curing agent was being poured in a polyethylene container, then it was subjected to partial degassing in a vacuum chamber. After curing the mixture small plates with one bubble were being cut out from it. Then these small plates with gaseous voids were being ground to 1 mm thickness. Special attention was being paid to central localization of the void.

The qualification of these plates with voids for testing was carried over with the aid of a microscope with an electronic converter which gives possibility of digital reading of a void diameter. This way twenty small plates with spherical voids were obtained. Diameters of the voids are from 0,15 mm to 0,92 mm. Then twenty epoxy resin samples were made each of them with the small plate inside. Fig.1. presents the shape of the sample. The plate with the void is in a central thin part of the sample.

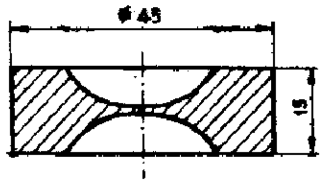

Fig.1. Cross-section of the sample with void

The samples were made according to the process engineering described in [1]. The dimple by one side of the sample was obtained as a result of special shaping of a mould bottom. The dimple by the other side was made by turning. The special attention was being paid to the surface of these dimples. They were carefully ground and then they were covered with silver paste.

During the measurements the sample with electrodes was being put in an insulating vessel filled with transformer oil.

3. Range of investigations

The investigations were carried out with the use of a system described in [1]. The high voltage circuit was reduced (a smaller coupling capacitor was applied) and placed in a shielding chamber.

It was determined to apply a stepped way of test voltage increase (every minute by 1 kV) with 50% overvoltage at each next step begining. As an initial voltage U_o it was decided to measure the least value of testing voltage U_p causing partial discharges in each sine wave period in the course of one minute.

Measurements of the maximum apparent charge value q_m in course of a minute were depended on reading on an oscilloscope screen every a few seconds and on notation of an amplitude of the biggest pulses,and at last on calculation of their average value. The similarity of investigation results to technical measurement results was the purpose of the averaging Standards require of measurements of repeated partial discharges.

First measurements of the initial voltage U_o and the maximum apparent charge q_m (at $U_p = U_o$) were made for all samples. Then the q_m value was being measured at voltage increase (every minute by 1 kV) to 30 kV.

As the latest measurements of a q_m value in dependence on time of partial discharges existence t were made at $U_p = 0$ and $U_p = 30$ kV.

4. Results of measurements and their analysis

4.1. Influence of void size on U_o and q_m

The inception voltage value U_o increases insignificantly with the increase of a void diameter d (Fig.2). Distinctly greater U_o values in comparison with U_o for voids made by drilling in sectional samples [1] find the explanation in dependen es of p.d. delay time on U_p and d [1,4].They point to a substantial significance of void surface defects griping electrons formed as a result of ionisation from outside sources or auto-ionisation.

The increase of the maximum apparent charge value q_m with the increase of a void diameter d is more distinct (Fig.2). The increase of d positively influences on p.d. development conditions as the result of increase of a void region in which an electric field intensity is as large as necessary for discharge appearance.

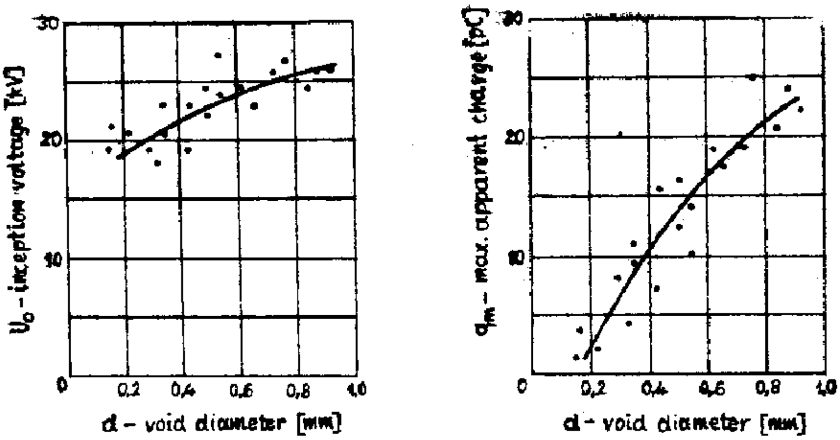

Fig.2. Results of measurements of p.d. inception voltage U_o and maximum apparent charge q_m as a function of void diameter d

4.2. Influence of test voltage value on q_m

The q_m value increases distinctly with the increase of a U_p amplitude (Fig.3), despite of a contrary effect of an exposure time. At the same time number of discharges increases in a U_p half-period. Greater slope of a voltage sinusoid in a region of an ignition of first p.d. at a greater U_p can cause an increase of an inception voltage and a q_m consequently. Certain probability exists that the increase of a q_m for greater U_p is caused, among others, by an increase of the capacity of resin layers placed between a void and electrodes as a result of a resin permittivity increase caused by charged particles penetration into dielectric which efects macroscopic polarization increase.

4.3. Influence of p.d. exposure time on q_m

The p.d. exposure time importantly influences on a q_m value in a few tens of minutes of the test (Fig.3). The q_m charge value decreases twice on the average in first hour time and it does not change later. Limiting

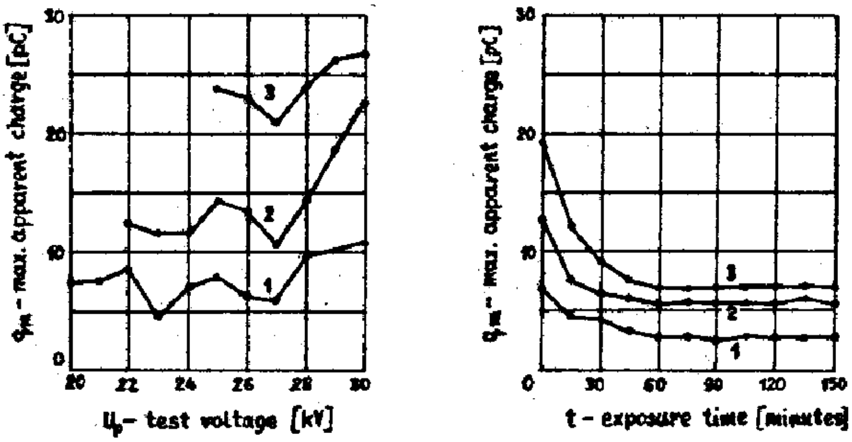

Fig.3. Results of measurement of p.d. maximum apparent charge q_m as a function of test voltage U_p and exposure time t
1 - d = 0,25 mm, 2 - d = 0,50 mm, 3 - d = 0,88 mm

p.d. development factors appear with lapse of time. An increase of a void wall conductance is such a factor for sure [5]. A spacing heterogeneity and a surface charge density decreases. It causes weakening of streamer p.d. connected with gliding discharges on the adventage of less intensive discharges, for instance of Townsend discharges.

5. Estimation of void volume on base of q_m

The received measurement results of maximum apparent charge q_m can be of some use for establishment of a dependence between it and void volume which has indentical or nearly identical dimensions in a parallel and perpendicular direction to electric field lines [1]. Taking adventage of investigated dependence $q_m = f(d)$, point 4.1, it was presented on Fig.4 the dependence of q_m on void volume V.

An analytical form of this dependence has a simple shape: $q_m = a \cdot V^b$

where: a - conctant dependent on accepted unit q_m and V measure, for considered case a = 45 pC/mm^3,

b - ratio of $q_m = f(V)$ variation, for considered case b = 0,52.

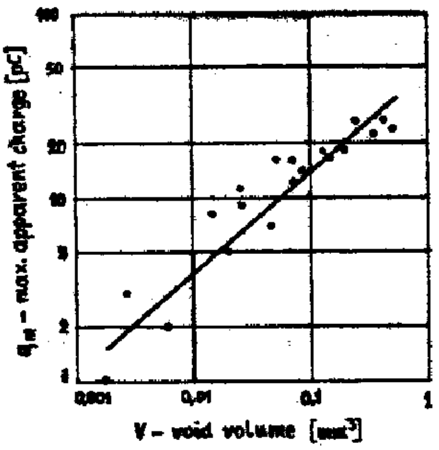

Fig.4. Dependence of p.d. maximum apparent charge q_m on void volume V

This dependence refers to virgin voids in epoxy resin with 1 mm sample thickness only. Carrying out the investigations of this dependence for wide range of the change of geometrical and physical parameters of samples with simultaneous establishment of a measurement condition influence would allow to utilise measurement results of the apparent charge for a quality estimate of insulation of practical insulating systems. The measurements of the q_m would become also an inseparable element of investigations during the research of new insulating materials and more perfect process engineering of insulating system production. Insulating systems are the most troublesome elements of high voltage devices during the designing and production and during using as well as.

R e f e r e n c e s

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