Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (22): 5483-5487, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.5483.5487

Research on Characteristic of Capacitor under Strong Stress

[1,2]Chen Yong and [1]Cheng Yong-sheng
[1]Institute of Electronic Engineering, CAEP, 621900, Mianyang, China
[2]Department of Electrical Engineering, Tsinghua University, 100084, Beijing, China

Abstract: Firstly, the physical mechanism of characteristic of capacitor under strong stress is discussed theoretically in the study. Secondly, as to the multi-fields coupling simulation, this study put originally forward a simple method to simulate the physical process by establishing the interface between ANSYS/LS-DYNA module and ANSYS/EMAG module in order to overcome the difficulty of no available software for the simulation at present. Finally, hammerblow test was carried out to study the phyiscal process fartherly and the test result was analyzed.

Key words: Strong stress, capacitor, capacitance, simulation

INTRODUCTION

A report from Sandia National Laborotary in the 55th annual fuze conference showed that capacity of high-voltage capacitor will change with the mechanical stress put on the capacitor. The capacity will rise or fall with different insulating materials inside the capacitor, but will resume while the stress released, as shown in Fig. 1.

From 3 aspects as theoretical analysis, simulation and tests, this study study the physical process of how to change with menchanical stress for the characteristic of the capacitor which is related to cross-subject between dynamics and electromagnetics. Among the previous means to study the topic, experiment is dominant while computational simulation is difficult to be applied because of absence of the software suitable for it. This study originally put forward a method to combining the simulation module of dynamics with one of electromagnetics which can make the simulation result of dynamic transfer to the simulation environment of electromagnetics in real time. This method make it possible to investigate deeply the electromagnetic characteristic inside capacitor enduring mechanical stress.

THEORETICAL ANALYSIS

High-voltage capacitor is made of insulative dielectric, electrodes and shell, as shown in Fig. 2.

In the condition of strong stress, the insulative dielectric inside the capacitor will be pushed or pulled in various degrees. According to the related result of investigation, the permittivity(ε) of the insulative dielectric will vary with the stress put on it which is due to the molecular structure destroyed partially and the randomness of the dielectric material rising up. After the stress is released, the molecular structure destroyed will

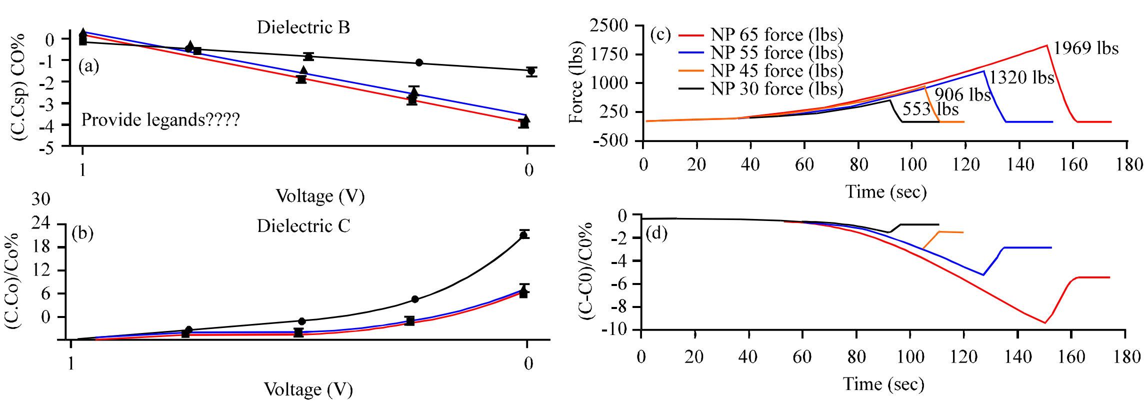

Fig. 1(a-d): Capacitance of the capacitor under the mechanical stress

Corresponding Author: Chen Yong, Institute of Electronic Engineering, CAEP, 621900, Mianyang, China

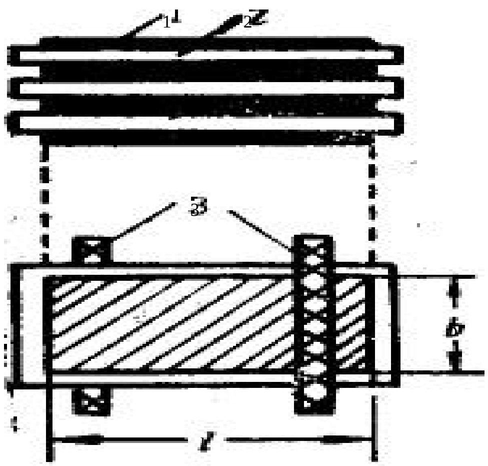

Fig. 2: Sketch of structure of the capacitor

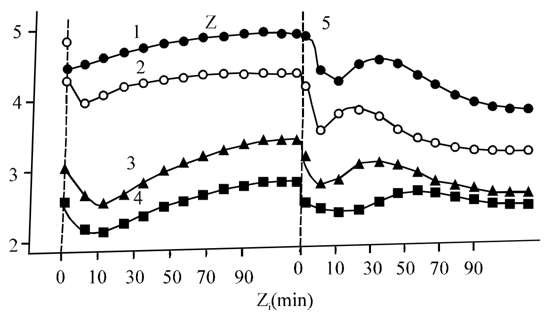

Fig. 3: Sketch of permittivity (ε) of insulative dielectric under stress

be recombined and this effect will be weaken (Bu, 2011). In the condition of dynamic stress, the process is repeatable, as shown in Fig. 3.

SIMULATION

Due to no current software for the simulation, the study combined the current software module (LS-DYNA) for dynamics simulation with the software module(ANSYS/EMAG) for electromagnetics simulation and set up the interface between them. On the basis of the method, simulation for characteristic of capacitor in the condition of strong stress was made in the study.

Setting up of model: In order to study the application of the simulation method more intuitively, a single model was adopted. As shown in Fig. 4, a rectangular capacitor impacts a steel plate with velocity of 500 m sec^{-1} and then rebounds. In the physical process to impact with the steel plate, finite elements of the capacitor will be pushed or pulled and then resume.

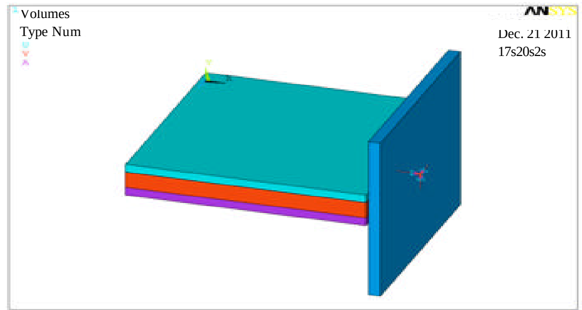

Fig. 4: Sketch of finite elements model

Table 1: Computational results of the capacitance at each time-step

Step	1	2	3	4	5	6	7
Capacitance (nF)	0. 5312	0.5303	0.5299	0.5246	0.5281	0.5396	0.5231

Simulation result and analysis: The study made the simulation for seven time-step which is 0.05 m sec, the simulation result shown as in Table 1. For the first time-step, sum and every vector (X,Y,Z) of electrostatic field is shown in Fig. 5 (Li, 2000).

The graph of capacitance changing based on the result of simulation is as shown in Fig. 6. Seen from the graph, capacitance is fluctuating in the process of impacting, for example, the capacitance of the time-step (1, 2, 3, 4) falls, of the time-step (4, 5, 6) rises and then of the time-step 7 falls. In the process of the step 5-7, the rapid change means that the stress on the capacitor has risen to maximum (Frost *et al*., 1993)

EXPERIMENT

Experiment condition and result: After fixing the capacitor on stamping machine firstly, charge the capacitor to the designated voltage (for instance, 1000 V), then cut off the power charging for it and t hen monitor the oscillation of the voltage across the capacitor with an oscilloscope (Agee *et al*., 1998). Due to no discharge circuit, it is impossible for the capacitor charged to the designed voltage to produce discharge so that the electric charges (Q) stored in the capcitor is considered as a constant. The hammer tests took place in two groups: monitoring the oscillation of the voltage across the capacitor varying with the designed voltage in the condition of the same hammer-tooth number (meaning the

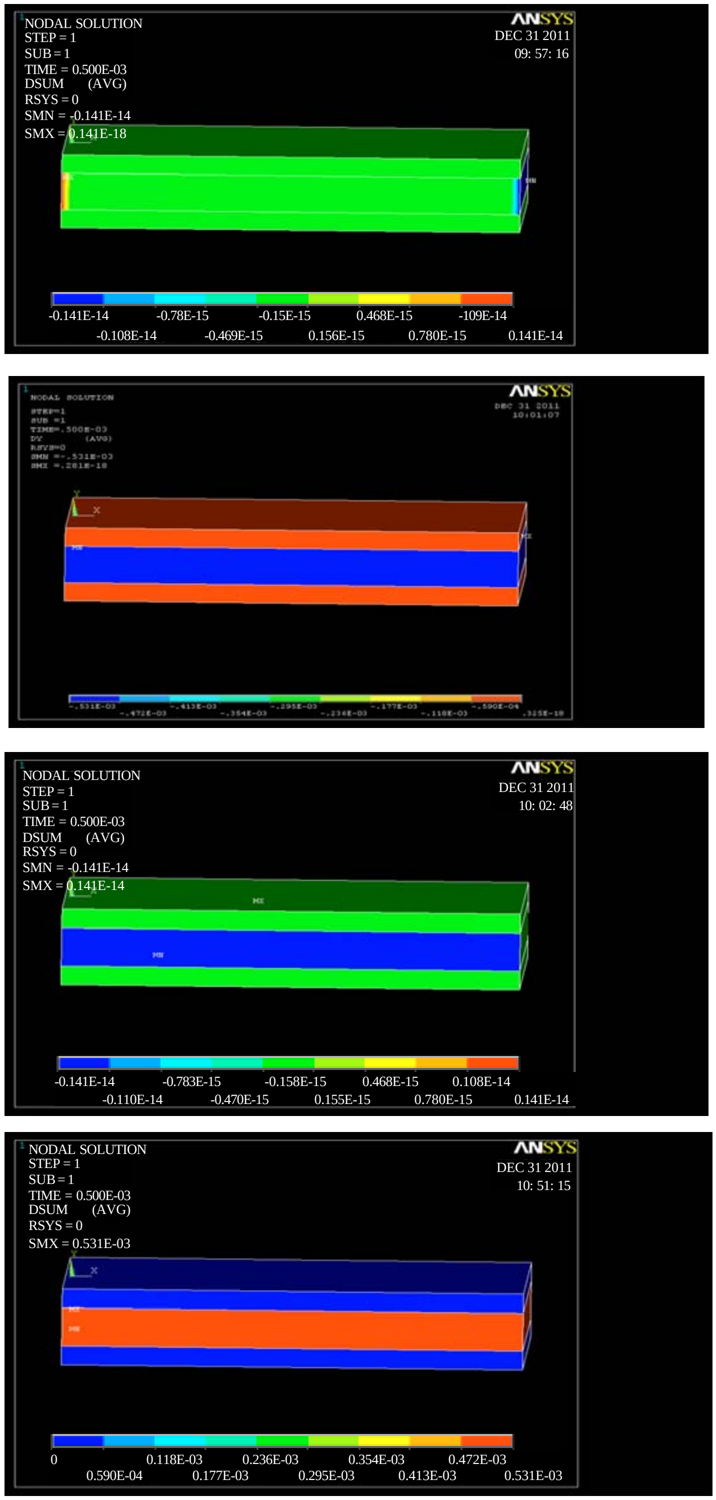

Fig. 5(a-d): Distribution graph of electrostatic across the capacitor at the first step

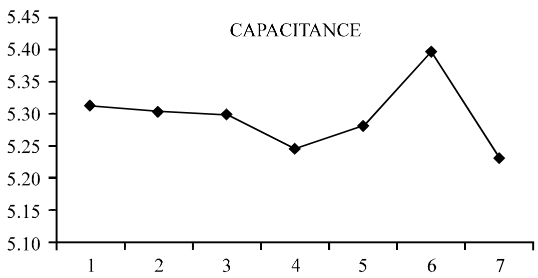

Fig. 6: Graph of capacitance change based on above computational results

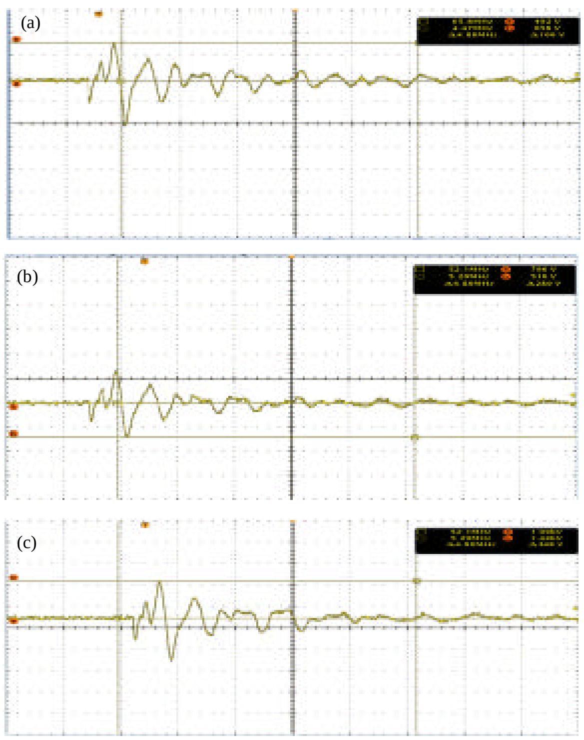

Fig. 7(a-c): Result of the first group tests (the same hammer-tooth No. 12) (a) Oscillation of the voltage under the 500 V designed voltage (max: 166 V), (b) Oscillation of the voltage under the 800 V designed voltage (max: 280 V) and (c) Oscillation of the voltage under the 1100 V designed voltage (max: 348 V)

same mechanical stress) in the first group tests and monitoring them varying with the hammer-tooth number in the condition of the same designed voltage in the second group tests. The test result is as showned in Fig. 7-8.

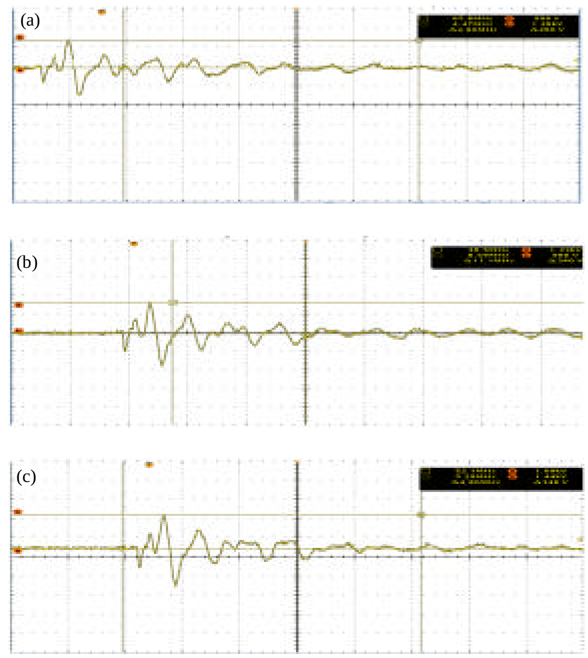

Fig. 8(a-c): Result of the second group tests (the same designed voltage: 1100 V) (a) Oscillation of the voltage under the 6 tooth hammer (max: 280 V), (b) Oscillation of the voltage under the 8 tooth hammer (max: 340 V) and (c) Oscillation of the voltage under the 6 tooth hammer (max: 348 V)

Analysis of test results: From the hammering test,the capacitors all show the oscillation of voltage under diffrent designated voltage: On the same hammering condition, the higher the voltage across the capacitor, the greater volitility of voltage across the capacitor; on the same voltage condition,the more hammer-tooth numer,the greater volitility of voltage across the capacitor. This phenomenon can be explained as follows:

$$U = Q/C$$

keep Q a constant, then $\Delta U = (Q/C2)\times\Delta C$.

On the condition of same hammering parameter,which means the capacity change ΔC is the same,volitility of voltage across the capacitor ΔU has linear relationship with Q. Furthmore, the initial power Q is linear with charging voltage, so there is also a linear relation between volitility of voltage across the capacitor ΔU and charging voltage.

On the condition of same charging voltage which means Q is not changed,volitility of voltage across the capacitor ΔU has linear relationship with ΔC but there is not a linear relation between volitility of voltage across the capacitor ΔU and hammering parameter, because hammering parameter is nonlinear with ΔC.

CONCLUSION

From above results the following conclusions can be drawn.

The physical mechanism of high-voltage capacitors' feature change has been theoretically analysed under high overloading stress: The structure of the insulating dielectric molecule is partially damaged under high overloading stress which leads to the increase of materials disorder and the decrease of ε. After that, this effect weakens, a part of damaged molecule would connect again, bringing about the increase of ε. Like this,the physical process would cycle again and again if it is under the condition of dymamic high overloading.

Because there haven't a multi-field coupling simulation software, the simulation calculation has been done by building data interface between LS-DYNA and EMAG. The simulation results show that under high overloading stress, deformation emerges inside the capacitors and the capacitor feature changes, the higher the stress, the more obvious changing.

The hammering tests indicate that there is a linear relation between volitility and magnitude of voltage across the capacitor on the same hammering parameters condition, corresponding to the identical overloading acceleration and stress,and that volitility of voltage across the capacitor is nonlinear with hammering paremeters at the same designed voltage.

Restricted to test condition and simulation tool, the simulation models are not completely consistent with the test conditions, so the results are just qualitative. Though, the research results will enhance its accuracy and credibility with continuous improvement on test and simulation.

ACKNOWLEDGMENTS

This study is supported by National Science Fundation of China (No. 51077118).

REFERENCES

Agee, F.J., C.E. Baum, W.D. Prather, J.M. Lehr and J.P. O'Loughlin *et al.*, 1998. Ultra-wideband transmitter research. IEEE Trans. Plasma Sci., 26: 860-873.

Bu, S., 2011. Permittivity of the composite material of conduction black-carbon and silicone rubber varying with mechanical stress. Phys. Eng., 21: 3-3.

Frost, C.A., T.H. Martin, P.E. Patterson, L.F. Rinehart, G.J. Rohwein, L.D. Roose and J.F. Aurand, 1993. Ultrafast gas switching experiments. Proceedings of the 9th IEEE International Pulsed Power Conference, Volume 1, June 21-23, 1993, Albuquerque, NM., USA., pp: 491-494.

Li, J.B., 2000. Numerical analysis of long conductor with rectangular section. J. Inform. Eng. Univ., 7: 167-171.