ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2013, http://www.imtuoradea.ro/auo.fmte/

REGARDING THE DYNAMIC CHARACTERISTICS OF FIBERGLASS REINFORCED EPOXY RESIN RODS RECOVERED FROM USED COMPOSITE ELECTRICAL INSULATORS

Daniel POPESCU[1], Mirela Cherciu[2], Alexandru STANIMIR[3], Roxana POPESCU[4]
[1]University of Craiova, daniel.popescu1119@yahoo.com
[2]University of Craiova, mirela_cherciu2005@yahoo.com
[3]University of Craiova, alexstanimir@yahoo.com
[4]University Politehnica Bucharest, roxpopescu@yahoo.co.uk

***Abstract*—**The paper presents a methodology for determining the dynamic characteristics fiberglass reinforced epoxy resin rods recovered from used composite electrical insulators. These are important for studying the dynamic stability and mechanical resistance under the action of external disturbing factors. There is presented the required measuring equipment and the rod mounting system for measurement. Experimental modal analysis (EMA) is used; the modal shapes are geometric representations of the dominant structure movements at proper frequencies. Identifying the proper oscillations is important for the given structure, resonance displacements indicating material wear and fissures in the framework. Research has identified the frequency response functions (FRF) and from their analysis it was determined the resonance frequency based on which can be determined the modal parameters of the analyzed rod.

***Keywords*—**composite electrical insulator, epoxy resin rod, modal analysis, proper frequencies, resonance frequency, modal parameters

I. INTRODUCTION

IT is well known the importance of composite electrical insulators in the functioning of 20 kV aerial power lines. Composite electrical insulators present several advantages, such as: long term operation, light weight, robustness, reduced maintenance costs, hydrofobicity, lower leakage current and resistance to chemical and atmospheric wear. Given their large scale usage, the need arises for recovering parts of them at the end of their life cycle (Fig. 1.), [4], [6].

Recent research shows concentrated efforts for recovering the silicone rubber from the insulator coating and the insulator core, a fiberglass reinforced epoxy resin rod [1], [2].

The resin rod plays an important part in the dynamic stabilization and mechanical resistance of the insulator against external factors.

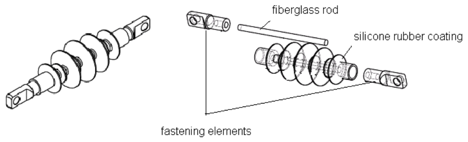

Fig. 1. Structure of a composite electrical insulator

II. DETERMINING THE DYNAMIC CHARACTERISTICS OF THE FIBERGLASS REINFORCED EPOXY RESIN ROD

The measurement setup is comprised of a Spider8 multi-channel data acquisition system (Fig. 2.) specially designed for digital recording of mechanical measures.

Spider8 is connected to a computer via parallel interface, RS232 or USB port and contains modules for measuring specific mechanical measures. The modules can be accessed and changed easily, and they can be:

- SR 55 – 4.5 KHz carrier frequency module for strain gauges (full/half bridge), inductive and piezoresistive transducers;
- SR 30 – 600 Hz carrier frequency module for strain gauges, inductive and piezoresistive transducers;
- SR 01 – DC amplifier.

Each channel has its own A/D converter which can be set from 0.1 to 9600 samples/second. The converters function in parallel synchronized by the measurement system, offering simultaneous acquisition on all 8 channels.

Fig. 2 shows a typical module connection and the measurement signal processing diagram.

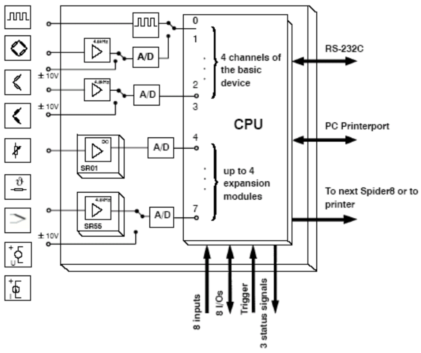

Fig. 2. Spider8 measurement signal processing

By attaching appropriate transducers/signal conditioners each monitored parameter can be converted to its voltage equivalent and recorded by the measuring system (Fig. 3.) [3].

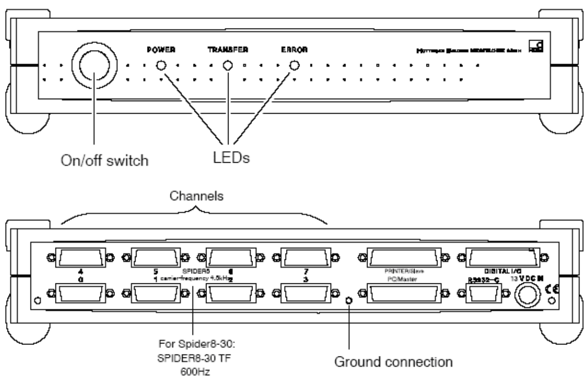

Fig. 3. Spider8 data acquisition system

The main characteristics of Spider8 are:

- analog input channels: 8
- maximum sampling rate: 9600 Hz/channel
- resolution: 12 bits
- numeric input channels: 8
- digital I/O: 24
- PC connection: RS232, USB

A signal conditioner is inserted into the measurement chain for the following reasons:

- to amplify the relatively weak signal provided by the accelerometer;
- to lower the high output impedance of the accelerometer such that the signal can be measured with common measuring devices (voltmeters, oscilloscopes, numerical acquisition systems, etc.);

There are two types of signal conditioners:

- voltage amplifier, for which the output voltage is proportional to the input voltage
- charge amplifier, for which the output voltage is proportional to the input electric charge

The main difference between the two types is that the voltage amplifier is highly sensitive to the charge variations that occur in the connection cables, whereas the charge amplifier is less sensitive.

The signal conditioner used in the measurement setup was a NEXUS 2692-A-0I4 manufactured by Bruel&Kjaer, which is 4-channel conditioner designed for working with charge transducers for measuring vibration, noise and forces. It allows choice of single or double integration for vibration speed and displacement. It also has 0.1, 1, 10 and 20 Hz high-pass filters and low-pass filters with user-selectable cut-off frequencies of 0.1, 1, 3, 10, 22.4, 30 and 100 kHz (40 dB/decade).

The main characteristics of the NEXUS 2692-A-0I4 (Fig. 4.) signal conditioner are:

- maximum input signal: 10 nC (peak)
- input signal protection: ≤ 300 nC (peak)
- amplification: 0.1 mV/pC ... 10 V/pC (-20 ... +80 dB with 1 nF transducer)
- transducer sensitivity: 10^{-19} ... 10^{-6} C/MU (MU = mechanical unit)
- frequency domain (-10%):

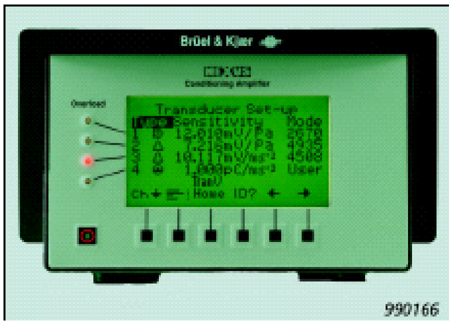

Fig. 4. NEXUS 2692-A-0I4 signal conditioner

The charge accelerometer used is a piezoelectric accelerometer that provides an electrical output signal proportional with the acceleration to which is submitted. Fig. 5. presents the general diagram of a piezoelectric accelerometer:

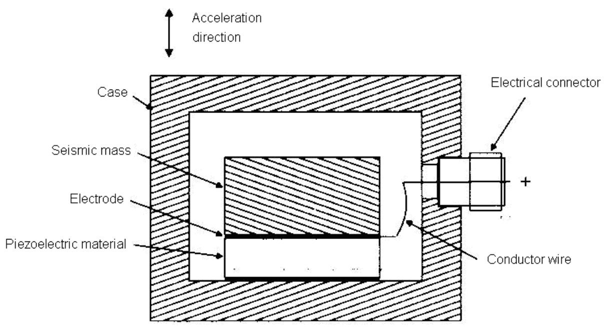

Fig. 5. Piezoelectric accelerometer

Usually the signal provided by the accelerometer requires conditioning before being analyzed with regular measurement or recording tools. Conditioning can be performed either by means of an integrated built-in conditioner or by means of an external signal conditioner (charge amplifier).

In order to measure the magnitude of oscillations and of high-level shocks, a Bruel&Kjaer 8309 extended frequency range piezoelectric charge shock accelerometer was used (Fig. 6.).

Its main characteristics are:

- sensitivity under load: 0.04 ± 2% pC/g
- acceleration domain: ± 15000 g
- frequency domain: 1 ... 39000 Hz
- resonance frequency: 180 kHz
- weight: 3 g

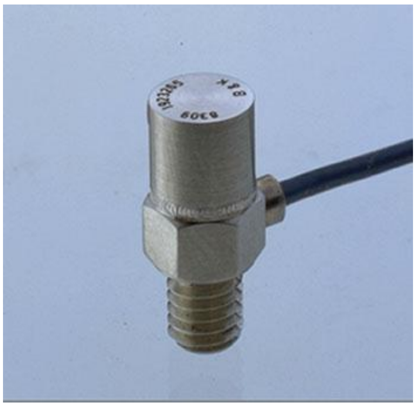

Fig. 6. 8309 piezoelectric charge shock accelerometer

Fig. 7. shows the entire measurement setup, [5]:

Fig. 7. Measurement system for determining the dynamic characteristics of the fiberglass reinforced epoxy resin rod

As far as it is concerned Experimental Modal Analysis (EMA), this constitutes the procedure for establishing the mathematical model of the structure based on experimental data obtained from measurements performed on the structure in a controlled vibration state.

The set of modal parameters defines the unique modal model associated to the real system and provides theoretical estimation of the system response to various excitation conditions applied to basis (earthquake), concentrated in various points (lifting, transport) or distributed along the structure (wind).

Identifying the self oscillations is important since localization of structural resonances in the excitation frequency domain leads to unwanted amplification of the vibratory response.

For a given structure, resonance displacement emphasizes material wear, fissures in the framework or loosening of assembly elements, [7].

Modal forms are geometric representations of dominant structure movements at proper frequencies. Modal form analysis emphasizes weak points and structure loosening or breaking areas. It also identifies those frequencies that may be dangerous for the structure or for the equipment. Vibration sensitive equipment shall not be placed in vibration antinodes; if it is not possible to change the equipment position, the structure must be optimized in order to obtain an acceptable vibration level.

The measurement system is comprised of:

- Spider8 data acquisition system, 12 bits resolution
- Signal conditioner NEXUS 2692-A-0I4, 0.01% linearity
- Bruel&Kjaer 8309 accelerometers, 2% linearity
- IBM ThinkPad R51 notebook

The recorded parameters are:

- response accelerations Acc1 to Acc4 (m/s^2)
- excitation force F (N)

The experiments were performed at the TCM Laboratory of the Faculty of Mechanics – University of Craiova.

Experiments were performed on a bracket-mounted resin rod with ϕ10 mm and length 290 mm (Fig. 8.).

Fig. 8. Bracket-mounted resin rod

The cylindrical rod was mounted on an SNA500 universal lathe. The measurement points P1, P2, P3 and P4 were set by dividing the rod into four 72.5 mm intervals at ¼ L, ½ L, ¾ L and L with respect to the left side. The B&K 8309 accelerometer was mounted successively at P1, P2 and P3 for measuring Acc1, Acc2 and Acc3 response accelerations.

Fig. 9. presents a typical recording obtained in case of

successive excitation at the lathe chuck P4 and measurement of the vibratory response in P1, P2 and P3. The recording is divided in two windows:

- the right side window shows the representation characteristics, such as:
    1. trace order (M#1, M#2, M#3, …)
    2. measurement points Degrees of Freedom (DOFs)
    3. measurement units
- the left side window shows the recorded characteristics and their identification: trace order, measurement point.

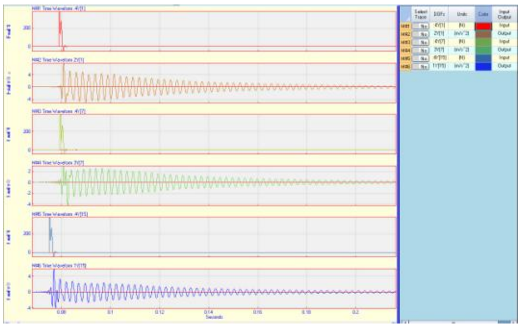

Fig. 9. Mounted rod; original recording. Excitation P4; measurement P1, P2, P3

The frequency response functions (FRF) defined as ratio between the Fourier transform of the response and the Fourier transform of the excitation can be determined (Fig. 10. & Fig. 11.).

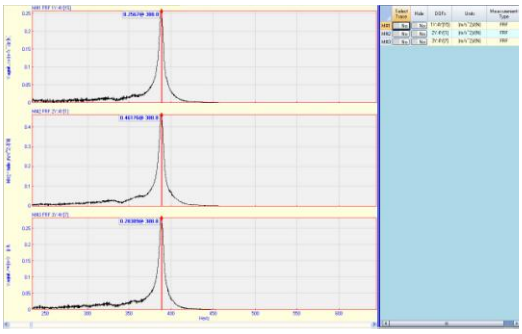

Fig. 10. Frequency response functions. Excitation P4; measurement P1, P2, P3

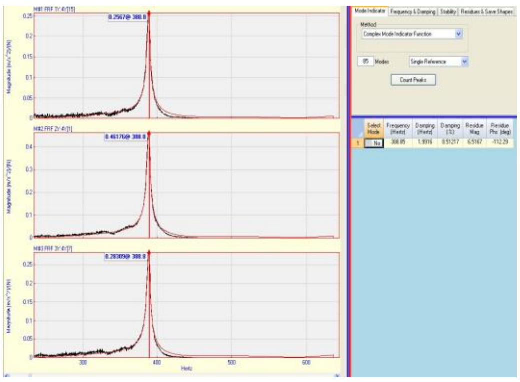

Fig. 11. Modal parameters. Excitation P4; measurement P1, P2, P3

III. CONCLUSION

FRF analysis shows the rod is characterized by a single resonant frequency. After running the modal identification module the modal parameters of the bracket-mounted rod are determined (Fig. 12.) as: resonant frequency – 388.85 Hz, fading – 1.99 Hz, critical fading ratio – 0.51%.

The modal shape of the mounted rod is presented in Fig. 12.:

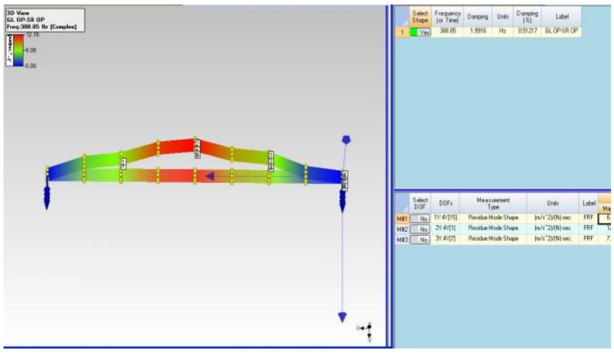

Fig. 12. Modal form of the mounted rod

REFERENCES

[1] Popescu, D., *Elements Regarding The Analysis Of Silicone Rubber Characteristics Obtined From Used Tile Of Electrical Composite Insulators*, Annals of the ORADEA UNIV., FAS. of MANAG. and TECHN. ENG., CD-ROM ED., VOL. XI(XXI), NR 1, ISSN 1583-0691, Ed. UNIV. din ORADEA, pp. 2106-2110, 2012.

[2] Popescu, D., Cherciu, M., *Regarding The Characterization Analysis Of Silicone Rubber Recoverable From Composite Electrical Insulators*, International Conference On Manufacturing Scienece and Education, MSE 2011, Sibiu, 2-5 Iun., Romania, PROCEEDINGS, Vol.I, ISSN 1843 -2522, ISI Indexed, pp. 75-79, 2011.

[3] Popescu, D., Buzatu, St., Gavrila, R., *Study Of Surface Roughness At Finishing Of Recovered Silicone Rubber*, The 21th International DAAAM Symposium – “Intelligent Manufacturing & Automation: Focus On Interdisciplinary Solutions”, 20-23rd October, Zadar, Croatia, ISSN 1726-9679, pp. 0005-0007, 2010.

[4] Popescu, D., *Investigation The Microstructure Of Silicone Rubber Recovered From Composite Electrical Insulators*, Annals of the ORADEA UNIVERSITY, FASCICLE of MANAGEMENT and TECHNOLOGICAL ENGINEERING, CD-ROM EDITION, VOLUME XX(X), ISSN 1583-0691 (e), Ed. UNIVERSITATII din ORADEA, pg.4125-4129, 2011.

[5] Popescu, D., *Tehnologii de recuperare si utilizare a materialelor din izolatoarele compozite cu izolatie externa de cauciuc*, Contract de cercetare dezvoltare din planul sectorial de cercetare dezvoltare MEF, 2008.

[6] Mahomed, A., *Properties Of Elastomer For Small Joint Replacements*, Doctoral Thesis, University Of Birmingham, 2008.

[7] Huba, A., Molnár, L.,Czmerk, A., Fischl, T., *Dynamic Analysis Of Silicone Elastomers*, Journal Materials Science Forum Volumes 473 – 474, pg.85-90, 2005.

[8] Aziz, T.,Waters, M., Jagger, R., *Analysis Of The Properties Of Silicone Rubber Maxillofacial Prosthetic Materials*, Journal of Dentistry 31 pp.67-74, 2003.