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рачунарство, аутоматику и нуклеарну технику

ЕТРАН 2021

и

8. интернационална конференција за електротехнику,
електронику и рачунарство

ИцЕТРАН 2021

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Радови укључени у Зборник прихваћени су од стране рецензената и приказани на 65. годишњој конференцији Друштва за ЕТРАН (ЕТРАН 2021) и 8. Интернационалној конференцији (ИцЕТРАН 2021) које су одржане од 08. до 10. септембра 2021. године у Етно селу Станишићи, Република Српска.

Број пријављених радова за конференције ЕТРАН и ИцЕТРАН је 162. Рецензије радова обавило је укупно 266 рецензената. Просечан број рецензената по раду био је 2. Прихваћен је и на конференцији приказан 141 рад који су публиковани у овом зборнику.

Заједничка тематска сесија "Дигитална Србија и Република Српска" окупила је научнике, стручњаке, истраживаче, представнике високошколских установа и представнике државе који су изнели своје погледе на значај и развој информационих технологија и вештачке интелигенције, на њихову улогу у развоју привреде и на одговарајуће промене у образовном систему. Координатори сесије били су проф. др Бранко Докић и проф. др Мило Томашевић, док су активни учесници сесије били Мр Срђан Рајчевић, Министар за научнотехнолошки развој, високо образовање и информационо друштво у Влади Републике Српске, др Саша Стојановић, помоћник Министра за просвету, науку и технолошки развој Владе Србије, проф. др Мило Томашевић декан Електротехничког факултета Универзитета у Београду, проф. др Зоран Ђурић, декан Електротехничког факултета Универзитета у Бањој Луци и проф. др Божидар Поповић, декан Електротехничког факултета Универзитета у Источном Сарајеву.

Координатор специјалне седнице на секцији Метрологија, под насловом "Стохастичке методе у мерењима био је Владимир Вујичић. Координатор специјалне седнице на секцији Рачунарство и вештачка интелигенција, под насловом "Шта рачунари данас не могу" био је Бошко Николић. У оквиру секције за електроенергетику одржана је специјална седница "Електроенергетика у 21. веку" у организацији Одбора за енергетику САНУ.

Члан Председништва Предраг М. Петровић био је координатор заједничке тематске седнице организоване као омаж Милољубу Смиљанићу, Почасном члану Друштва за ЕТРАН и Генералном секретару Академије инжењерских наука. Уз поруку "Драги Мићо, дивљење и поштовање са захвалношћу" говорили су Предраг М. Петровић, Дејан Б. Поповић, Председник ЕТРАН-а.

Председник ЕТРАН-а, академик Дејан Б. Поповић био је координатор заједничке тематске седнице организоване као омаж академику Нинославу Стојадиновићу, бившем Председнику ЕТРАН-а, члану Председништва и Заслужном члану Друштва за ЕТРАН. Уз поруку "Остајемо да негујемо његове идеје" говорили су проф. др Данијел Данковић, Дејан Б. Поповић, Председник ЕТРАН-а и Братислав Миловановић, академик АИНС.

Посебно се захваљујемо организаторима из Републике Српске и домаћинима из Бијељине, који су допринели стварању услова за рад и плодну размену мишљења и критички осврт на резултате у оквиру свих секција.

Београд, 12.10.2021.
Академик Слободан Вукосавић
заменик председника ЕТРАН

The papers included in the Proceedings were selected in a peer review process and presented at the 65th annual conference of the ETRAN Society (ETRAN 2021) and at the 8th international Conference IcETRAN 2021, both held September 8 – 10, 2021 in Stanišići ethno-village, Republic of Srpska, Bosnia and Herzegovina.

The number of the submitted papers for the ETRAN and IcETRAN conferences was 162 in total. Peer reviewing was done by 266 reviewers. The average number of reviewers per paper was 2. A total of 141 papers was accepted, presented at the two conferences and published in full in these Proceedings.

The joint thematic session "Digital Serbia and Republic of Srpska" gathered scientists, experts, researchers, representatives of universities and governmental representatives who presented their opinions about the significance and development of information technologies and artificial intelligence, their role in the economic development and the corresponding changes in the educational system. Session coordinators were prof. dr. Branko Dokić and prof. dr. Milo Tomašević, while the active participants of the session were Mag. Sci Srdjan Rajčević, Minister of Scientific and Technological Development, Higher Education and Information Society in the government of the Republic of Srpska, dr. Saša Stojanović, Assistant Minister of Education, Science and Technological Development in the government of Republic of Serbia, prof. dr. Milo Tomašević, Dean of the School of Electrical Engineering, University of Belgrade, prof. dr. Zoran Djurić, Dean of the Faculty of Electrical Engineering, University of Banja Luka and prof. dr. Božidar Popović, Dean of the Faculty of Electrical Engineering, University of East Sarajevo.

The coordinator of the special session within the Metrology Section titled "Stochastic Methods in measurements" was Vladimir Vujičić. The coordinator of the special session within the Computers and Artificial Intelligence Section titled "What computers cannot do today" was Boško Nikolić. Within the Power Engineering Section a special session "Electric Power in 21st Century", organized by the Power Engineering Board of Serbian Academy of Sciences and Arts (SASA).

The member of the ETRAN Society Board Predrag M. Petrović was the coordinator of the plenary thematic session organized as a homage to late dr. Miloljub Smiljanić, Fellow of the ETRAN Society and Secretary General of the Serbian Academy of Engineering Sciences. With the message "Dear Mićo, admiration and respect with gratitude" the speakers were Predrag M. Petrović and academician Dejan B. Popović, ETRAN Society Chairman.

The ETRAN Society Chairman, academician Dejan B. Popović was the coordinator of the plenary thematic session organized as a homage to late academician Ninoslav Stojadinović, Member of ETRAN Society Board and a Fellow of ETRAN Society. With the message "We continue to forward his ideas" the speakers were prof. dr. Danijel Danković, academician Dejan B. Popović, ETRAN Society Chairman and Bratislav Milovanović, academician of Serbian Academy of Engineering Sciences.

We express our special gratitude to the organizers from the Republic of Srpska and our hosts from Bijeljina who contributed to creating working conditions and a fruitful interchange of opinions, as well as a critical review of the results within all sections.

Belgrade, October 12, 2021.
Academician Slobodan Vukosavić
Vice-Chairman of the ETRAN Society

Reconstruction of fiber reinforcement in epoxy-based composite

Aleksandar Stajčić, Vojislav V. Mitić, Cristina Serpa, Branislav Randjelovic, Ivana Radović

***Abstract*—Polymer matrix composites (PMCs) are very attractive materials due to a possibility to achieve versatile properties by combining with ceramic or metal reinforcement in different shapes and sizes. As a result, PMCs have found application in nearly every field, from household appliances to aerospace industry. Modern microelectronic devices contain conductive polymers with fillers that enhance their electrical properties. In addition, PMCs are being used as insulators and adhesives, contributing to the long life of electronic devices. Epoxy resins are the most commonly used insulators and adhesives. In order to improve their fracture toughness, glass fibers can be used as an efficient reinforcement. However, with the purpose of designing a composite with good mechanical properties and durability, deep knowledge of microstructure is required. In addition, microstructural analysis can be used to connect shape and size of pores or reinforcement with various physical properties. Fractal nature analysis is a valuable mathematical tool that can be employed for different shapes and forms rendering. In this manner, successful design and prediction of composite's properties could be obtained. In this research, field emission scanning electron microscopy (FESEM) images were used for fractal analysis of glass fibers, with the aim of reconstructing the shape.**

***Index terms*— Fractal analysis; Composites; Epoxy; Microelectronics.**

I. INTRODUCTION

Composites represent multiphase materials containing two or more phases distinct by an interface [1-3]. Physical properties of composites are significantly different from the initial constituents' properties [4,5]. Civilization modernization was followed by increased production and development of composites both at the research and industrial scale. With composite design and processing, structural, thermal, electrical and other properties of the constituents are improved. Synergetic effect of matrix and reinforcement properties results in lightweight materials with high toughness and strength that can be resistant to corrosion, chemicals and temperature [6]. Nowadays, there are many efficient ways to process composite with targeted functional properties, with structure control at micro- and nanoscopic level [7-12]. Polymers are very attractive as matrix materials in composites, due to their low price and density, as well as wide range of good physical and chemical properties. Conductive polymers like poly(vinylidene fluoride) polypyrrole are investigated and implemented in various electronic parts. Composites with epoxy matrix are used as insulators, offering device stability and durability [13]. Since epoxy generally has low fracture toughness, fibers are usually incorporated for the reinforcement. They increase toughness, specific strength and modulus of elasticity [14,15] In order to avoid delamination and fiber separation from the matrix, thorough insight into the structure in desirable [16-18]. Fractal nature analysis is a powerful mathematical tool for the investigation of materials morphology that is used for characterization of grains and pores [19]. However, it can also serve to describe and predict the shape and size of reinforcement, enabling more efficient future composite design. In this manner, processing-structure-property circle can be closed. FESEM images can be used for the shape and size reconstruction of the fibers.

A. Fractal nature analysis

The fractal nature exists within physical systems structures and contact surfaces, from microstructures, down to the nano-scale level, up to the global bulk and massive shapes. Fractal nature analysis presents a possible approach for the investigation of contact phenomena establishing the grain contacts models, offering ceramics and other materials structure analysis, description and prediction of grains' and pores shape, along with relations between structure and electric-dielectric properties. Contribution of fractals correction could be observed and explained on intergranular Heywang capacity model, Schottky barrier, Curie-Weiss law, Clausius-Mossotti relation and other parameters in the field of dielectric and ferroelectric materials, by introducing complex fractal correction factor α (grain and pores surface influence and Brownian particle motion). The development of fractal

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analysis idea is inspired by self-similarity in nature biosystems, where the chaotic structures could be controlled by recognized geometry structure or just to have disorder controlled towards the order. One of the goals is to recognize and develop the bridge between biosystem of living organisms and physical systems condense matter particles. In this manner, we use the inspiration from nature for better understanding the particles physics motions, which could be observed as biomimetic system.

Every fractal object (FO) has its fractal dimension – Hausdorff dimension (D_H), a real number, smaller compared to the geometric dimension of the FO minimal space. Influence of pores' and grains' fractal dimension on materials properties has already been established [20-25]. Unlike ideal, natural fractals have scale-dependent fractal dimension [26]. Nature objects, such as water surface, air particles, trees and many others do not show intrinsic structural, but statistical self-similarity; therefore, they are considered as almost fractals. Reconstruction of such shapes requires modified mathematical approach, offered by fractal geometrical analysis. This mathematical technique can be performed on field emission scanning electron microscopy (FESEM) images, by identifying fiber phase and pores shapes and boundaries, as well as fiber-matrix bonding at the interface. In this study, fiberglass mat was used for the reinforcement of epoxy. FESEM image of enlarged fiber after the composite fracture was used for the reconstruction of data.

II. THE METHOD

A. *Fractal reconstruction of data*

Fractal nature analysis of experimentally determined physical properties is performed using a novel affine fractal regression model described by the equations published in our previous research. The aim is to find coefficients that fit experimental data for the following equation system:

$$\varphi\left(\frac{x+j}{p}\right)=a_j\varphi(x)+b_jx+c_j \tag{1}$$

where $x\in[0,1)$, $0\le j\le p-1$, a_j represent fractal and b_j directional coefficients, with $0<|a_j|<1$, with domain [0,1), p stands for fractal period. Real solution equation system is called fractal function $\varphi:[0,1)\rightarrow R$, having mathematical fractal structure – function graph plot represents fractal curve. Higher a_j appear in the case of strong fractal oscillations. The curve fractal level defined by the equation system is L; the first fractal level is replicated in the entire domain over every of the p sub-intervals, building the second fractal level.

In order to obtain coefficients that fit the data, explicit solution of the problem that depends on the p-expansion of numbers in [0,1) is used. For L=2, this solution is

$$\varphi(0)=\frac{c_0}{1-a_0} \tag{2}$$

$$\varphi\left(\frac{\xi_1}{p}\right)=a\xi_1\frac{c_0}{1-a_0}+c\xi_1,\ \xi_1\neq 0 \tag{3}$$

$$\varphi\left(\frac{\xi_1}{p}+\frac{\xi_2}{p^2}\right)=a\xi_1\left(a\xi_2\frac{c_0}{1-a_0}+c\xi_2\right)+ \tag{4}$$

$$b\xi_1\frac{\xi_2}{p}+c\xi_1,\ \xi_2\neq 0$$

For obtaining the best coefficients, the theoretical approach computes the SSR - sum of square residuals in between the formal definition and the real values. Afterwards, the partial derivatives of SSR are equalled to zero, for minimizing the error. The best solution of the problem is given when:

$$\frac{\partial SSR}{\partial a_j}=0,\frac{\partial SSR}{\partial b_j}=0,\frac{\partial SSR}{\partial c_j}=0 \tag{5}$$

for all j=0,1,2,…,p-1. This is a problem with 3p parameters, to estimate where the equations to solve are nonlinear.

The mathematical analytical solution of this partial derivative system is not possible to compute, and a numerical approach is needed. With the software for numerical computation of the solution, called Fractal Real Finder, we worked on samples and obtained estimated curves and estimates of Hausdorff dimension. With the input of the real data, the program executes simulations and gives an output with a fractal curve as modelled above.

With the estimated fractal curves, we may estimate the Hausdorff dimension. The Hausdorff dimension is an indicator of the chaotic/irregular data behavior. The classical dimension is represented by integer: 1 for lines and curves, 2 for 2D objects, 3 for solid 3D objects. There are structures that have characteristics in between two integer dimensions. In that case, we may estimate a non-integer dimension. The fundamental theoretical mathematical non-integer dimension is Hausdorff dimension, sometimes referred as fractal dimension. The box dimension is a simplified indicator that provides estimates for the real Hausdorff dimension of real data.

Proposition. The Hausdorff dimension D of the function graph, φ solution of the above system is upper bounded by the solution of:

$$\sum_{j=0}^{p-1}\beta_j^{\,D}=1 \tag{6}$$

$$where\ \beta_j=max\left\{\frac{1}{p},|a_j|\right\},0\le p\le p-1$$

The coefficients with fractal relevance are those a_j such that $|a_j|>1/p$.

From the following image (Figure 1), we selected a centre small part (lighter bar) and zoomed in it to a new image (Figure 2).

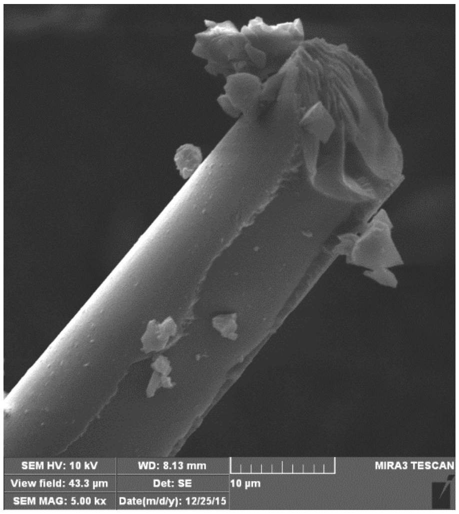

Fig. 1. FESEM of a broken glass fiber.

III. RESULTS AND DISCUSSION

We inserted red points circling a contour of the tip of the glass fibre in a polar grid, as the following figure.

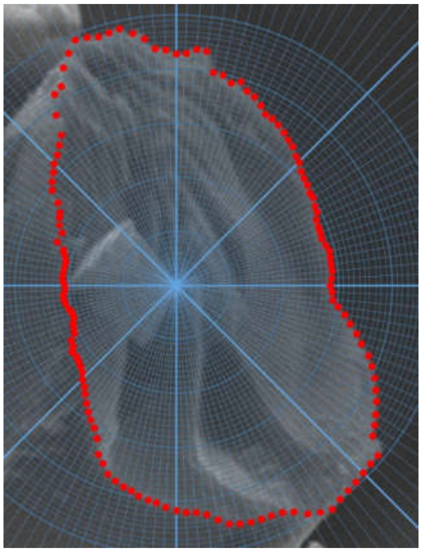

Fig. 2. Enlarged tip of the broken fiber.

We introduced red points in a border line. The fractal reconstruction is plotted in the figure next to the selected part of the image. In this case, we put the default domain in the vertical axis and upside down to match with the position of the image.

From a change of variables, from polar to cartesian variables, we run the Fractal Real Finder software for the sequence of radiuses and obtain the estimated fractal model with coefficients, as in Table below. The sequence of points is the set of radiuses corresponding to $p^L = 12^2 = 144$ angles around the image.

TABLE I
ESTIMATED COEFFICIENTS FOR THE FRACTAL CURVE OF THE RADIUS

	0	**1**	**2**	**3**	**4**	**5**
a_j	0.081	-0.044	0.012	-0.002	-0.017	0.014
b_j	0.731	-2.212	-0.805	-0.098	0.603	1.362
c_j	3.951	4.989	2.695	2.118	2.156	2.852
	6	**7**	**8**	**9**	**10**	**11**
a_j	0.027	-0.057	-0.013	0.021	-0.013	0.024
b_j	0.695	-0.005	-1.654	-0.037	0.517	0.712
c_j	3.957	5.072	4.608	2.821	2.868	3.304

This fractal reconstruction reveals no fractal coefficients (those bigger than $1/p = 0.8(3)$) and, in consequence, the corresponding Hausdorff estimate is 1. Returning to polar coordinates (radius and angle), we plot the estimated curve as follows.

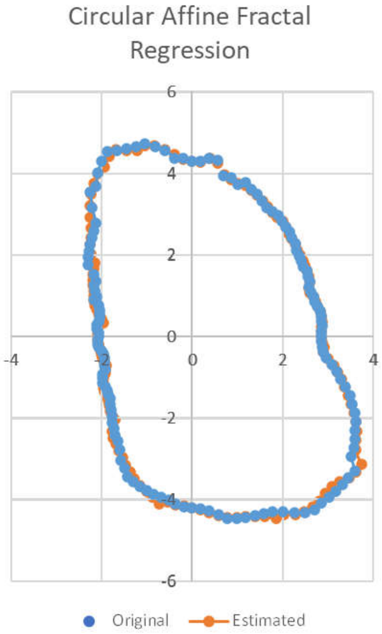

Fig. 3. Fractal curve of the fiber shape

IV. CONCLUSION

In this paper, fractal nature analysis was applied on fiber-reinforced composite for the reconstruction of fiber shape. The analysis with software Fractal Real Finder, fractal curve depicting the shape was obtained, as well as Hausdorff dimension of 1.21968. This indicates that the fibers have been successfully reconstructed. The finding achieved in this study enables the use of the fractal software analysis for the design and prediction of efficient reinforcement for epoxy-based composites in the future.

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