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Mechanical Properties and Microstructure Fractal Analysis of Refractory Bauxite Concrete

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Abstract:

The surface topography analysis via fractals as a means of explanation of composite materials mechanical and microstructural characteristics has hardly been reported so far. This study proposes a method of fractal analysis and its application to refractory bauxite concrete surface tribological investigation. Fractal dimension, profilegrams and fast Fourier transform method are introduced and supported by the adequate software for analysing contours and surface roughness, depending on the observation scale and also numerically depending on horizontal lines intercepted by the investigated profile. Also, the Richardson method and Kaye modification are applied to distinguish textured and structured aspect of grain contour geometry. Microstructural investigation was carried out using a scanning electron microscope. Using the fractals of the grains contact surfaces, a reconstruction of microstructure configuration, as grains shapes or inter-granular contacts, has been performed. Obtained results indicated that fractal analyses of contact surfaces of different shapes were very important for the prognosis of the concrete behaviour. The novel approach to the investigation of refractory concrete properties was successfully conducted, as a result introducing fractal identification as a means of composite materials performances evaluation.

Keywords: *Refractories; Mechanical strength; Sintering; Surface topography analysis; Fractal dimension; Fractal surfaces.*

1. Introduction

The continuous development of the high-temperature/refractory materials industry required substantial advances and innovations in the casTab. preparation and application procedures, which consequently led to significant improvements in the refractory products performances [1-3]. Regarding the contemporary practice, refractory concretes are employed in a variety of metallurgical furnaces, cyclic thermal loading structures, blast furnace linings, steel making ladles, electricity producing reactors, etc [4, 5]. A number of factors influence the failure mechanism of a refractory concrete built in a construction: oxidation due to high temperature and air interaction, erosion due to the movement of molten fluids, microstructure

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differential expansion, and macroscopic thermo-mechanical stress induced by the thermal gradient [6]. The exposure to high temperatures and sintering process are factors that shape the characteristics and the performance of a refractory concrete. Shotcrete is a sprayed refractory concrete that is mainly utilized for complex shapes, unreachable construction parts, and in restoration works. Main advantages of shotcrete are: excellent adhesion to the base material, rapid strength development, perfect cavities and cracks filling, and extremely short setting time [7-9].

A refractory concrete mix-design is based on temperature-resistant cements and aggregates, and mineral or chemical additives employed to improve either flowability or certain chemo-physical and/or mechanical properties. The fly ash shows adequate behaviour at elevated temperatures, and therefore its application in the design of refractory materials in not uncommon [10-15]. Performing characteristics of the fly ash used as microfiller and/or additive in the design of a concrete are often being enhanced by mechanical activation procedure. The activated state is induced by the increase of the specific surface area and number of the atomic defects, and high concentration of dislocations in the activated material. Activation does not only effect the change of the particle size, it is also a complex chemo-physical process which induces the increase in potential energy, chemical activity and system reactivity [16-19].

In this study, the effectiveness of the mechanical activation of fly ash as a component in refractory concrete (shotcrete) production was investigated through experimental program. The performance of the bauxite concrete was determined in terms of compressive and flexural strength, porosity, refractoriness and refractoriness under load. The goal was to obtain the refractory concrete based on a secondary raw material which would have matching mechanical and thermal properties to those of standard refractory concrete, and furthermore to analyse and explain the concrete characteristics by means of the fractal dimensions theory.

2. Experimental: materials and methods

The investigation was conducted on a refractory concrete of sprayed type (in further text: refractory shotcrete, SCBF) prepared from refractory bauxite aggregate (calcinated bauxite, LKAB Minerals, Luleå, Sweden) and chamotte filler (Zibo Zhuoyue Refractory Material Co. Ltd., China). High aluminate cement (Secar 70/71, Lafarge, France) was applied as a refractory binder. A solid powdery chemical admixture Litopix–P56 (Zschimmer & Schwarz, Germany) was added to improve the workability of the green mixture and to prevent dissipation of the grains during application of the shotcrete. The fly ash was added to the composition of SCBF, where it can be regarded either as partial replacement of cement or as a filler. The fly ash originates from the filter system of a lignite-fired power plant in Serbia, and it conforms to the F-class according to the ASTM C 618. The ash was collected directly from the filter and transported to a special closed silo, where it was resampled by the quarter method.

The chemical compositions of the components applied in the mix design of SCBF shotcrete are given in Tab. I. The chemical analyses were performed by means of atomic emission spectroscopy technique: PinAAcle 900 Atomic Absorption Spectrometer (Perkin Elmer, Waltham Massachusetts, USA). The loss of ignition (LoI) of the samples was determined by the weight difference between temperature 20°C and 1000°C.

The grain-diameters of the initial fly ash sample varied from several micrometres to 2 mm, therefore the mechanical treatment was applied as a means of the grain-size reduction, and consequently, in improvement of the grain size distribution related characteristics. The fly ash was submitted to the mechanical activation in an ultra centrifugal mill ZM 200 (Retsch, Düsseldorf, Germany) before mixing with refractory cement. The applied high speed rotor mill reduced the grain size due to the impact and shearing effects that occurred between rotor and fixed ring sieve. The material feed size was less than 3 mm, and produced final fineness was less then 40 µm. Batch size of the mill was 300 ml. The working speed at 50 Hz was 10000 min^{-1}. The activation period was 20 min, based on previous researches [13]. The ash grain size fraction content was analysed by cyclo-sizer diffraction particle size analysis (Cyclo-sizer: Warman International LTD, Australia). The fly ash particle size grading is given in Fig. 1.

Tab. I Chemical composition of refractory shotcrete components.

Oxide, %	Cement	Bauxite	Chamotte	Fly ash	Admixture
Al_2O_3	70.75	83.28	30.99	59.95	4.00
SiO_2	0.17	9.03	55.55	17.82	24.00
CaO	27.81	1.1	2.75	7.99	
MgO	0.19	0.27	0.55	1.97	
Fe_2O_3	0.2	0.69	1.99	7.4	
Na_2O	0.16	0.09	0.29	0.35	33.00
K_2O	0.01	0.45	1.57	0.59	
Ti_2O	0.01	4.8	1.28	0.68	
P_2O_5					19.00
LoI (at 1000°C)	0.70	0.29	5.03	3.25	20.00

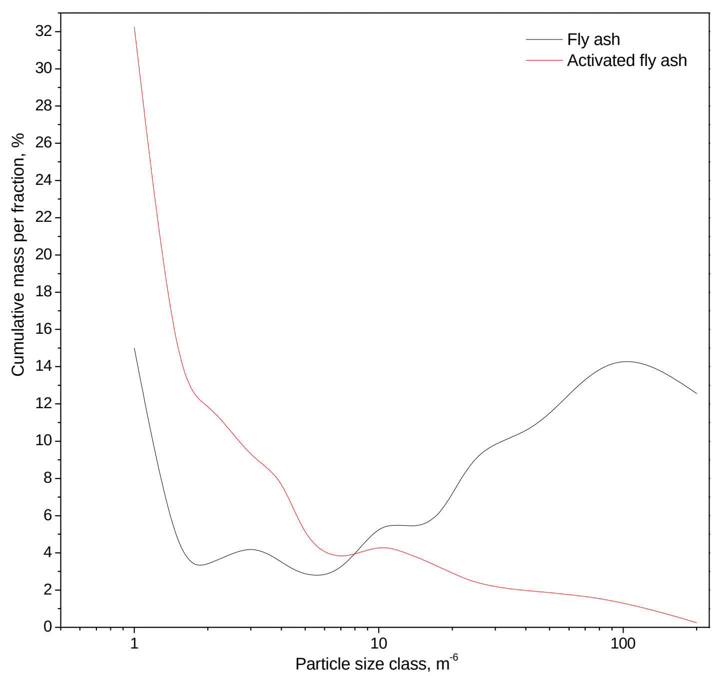

Fig. 1. The particle size grading of the original and activated ash.

Specific surface area (SSA) of the ash was determined via Brunauer–Emmett–Teller (BET) method. The initial ash SSA was 295.17 $m^2·kg^{-1}$, and after 20 min of activation SSA increased more than two times and reached the value of 597.85 $m^2·kg^{-1}$.

The concrete was prepared according to the procedure given in SRPS EN 1402-5:2009. The procedure was conducted in two steps regarding water addition in order to prevent segregation. The green mixes of SCBF concrete were made to obtain a slump of 150 m^{-3}. The w/b ratio was kept as low as possible retaining optimal workability of the mixture (applied water/(cement + FA) ratio was 0.44). The mixture was homogenized using a laboratory pan-type mixer 65-L0006/AM (Controls Inc., USA). The initial sequence started with dry mixing of aggregate with binder for 2 min, after which the 80 % of water and the admixture were added and homogenized for 3 min. After the mixture rested for 2 min, remaining part of water was added and mixture was homogenized for additional 2 min. The specimens were cast in steel moulds (160×40×40 mm prisms and 200×200×200 mm cubes) by a self-flow method. The moulded samples were kept covered with a plastic sheet to prevent water loss for following 24 h. After demoulding, the samples were dried at 110°C for 24 h. Dry samples were submitted to thermal treatment in a laboratory furnace at various temperatures up to 1400°C with 2 hours delay at each temperature. Physical and mechanical properties, i.e. bulk density, porosity, crushing and flexural strength, were tested on the prepared concrete prisms and/or cubes. Total porosity was estimated by a mercury porosimeter Pascal 440 (Thermo Fisher Scientific, Inc., USA) with a pressure applied up to 200 MPa. Thermal properties (refractoriness and refractoriness under load) were tested on the samples of adequate shape and dimensions cut from the original samples. The details of the concrete mix proportions are given in Tab. II.

Tab. II Mix-design of the refractory bauxite shotcrete

Component	Cement	Ash	Admixture	Bauxite	Chamotte
Content	24%	13 %	1 % of total concrete mass	40% (1-4 mm: 30%; 0-1 mm: 10%)	Σ 23% (>74 µm: 2%; 44-74 µm: 7%; 33-44 µm: 5%; 23-33 µm: 6%; 11-23 µm: 1%; 3-11 µm: 1%; 0-3 µm: 1%

The microstructure of the shotcrete samples was characterized by scanning electron microscopy method (SEM) using a JEOL JSM-5800 microscope. Samples were crushed, and parts of original samples were used in SEM investigations. The surface was not polished and the samples were covered with gold powder.

3. Fractal analysis

Even though the first complete book on fractals by Mandelbrot [20] gave only global insight into a new geometry, the fractal methods managed to spread through all scientific areas. Especially physics and chemistry embraced this knowledge by such making a huge benefit from the application of fractal methods. However, very few scientific attempts in application of the fractal dimension methods were recorded in the area of powder processing and the sintering process investigation. Except publication by Kaye [21], there are not too many books that systematically treat fractal nature of sintered materials. A number of papers of these authors [22-25] deal with composite and ceramic materials considering different aspects of fractality: relation of the microstructure and its fractal dimension FD, the most important quantity attached to some fractal object. The fractal analysis conducted here followed previous investigation on the similar type of material [27]. The goal of this study was to further prove the efficiency of the fractal approach in the investigation of mechanical and microstructural related parameters of concrete composites.

The first step in the conducted fractal analysis of the SCBF refractory concrete was to choose an adequate SEM microphotograph on which fractal dimension of the specimen surface would be estimated. The photograph ought to represent a complex enough surface, and it is selected according to the impression of observer. The next step is extracting 3D data from the SEM photograph, which usually contains peaks at light parts and valleys at dark parts. Afterwards, such numerically generated surface is used to construct isolines (isarithm lines). Successive close-ups of different parts of isoline maps might reveal nonlinear self-similarity of patterns, which is the first sign that a surface has fractal structure. The final step is the fractal dimension estimation. Fractal dimension of a Euclidean smooth surface is equal to its topological dimension FD = TD = 2. However, if a surface has fractal structure, its fractal dimension becomes bigger than 2 and it may be any fraction or irrational number between 2 and 3. Therefore, 2 < FD < 3, and higher values of FD correspond to more complicated surfaces. Upon confirmation of the possibility of fractal dimensions calculation on the refractory bauxite concrete surface, the samples are subjected to further analysis of the fractality parameters.

4. Results and discussion

The influence of the mechanical activation on the fly ash as a componential material was investigated through analyses of the physical, mechanical and thermal properties of the bauxite refractory concrete SCBF. The concrete properties were tested at various temperatures from 20°C to 1400°C. Exposure of the cementitious materials to the elevated temperatures is associated with a number of chemo-physical transformations which affect the stability of the internal structure and influence the strength of a material. The causes of these transformations are dehydration and/or decomposition of the cementitious compounds, different expansion values of the constituents, i.e. thermal mismatch, and internal pore pressure. The initial sign of the changes that occurred within cementitious system of the SCBF concrete is difference between bulk densities measured at the starting and ending point of the thermal exposure. The experimentally obtained bulk density of the control SCBF sample at ambient temperature was 2405 kg·m^{-3}. After exposure to 1400°C, the bulk density of the same sample was 2085 kg·m^{-3}. The behaviour of the SCBF under mechanically induced load was quantitatively evaluated by measuring the compressive (CS) and flexural (FS) strengths upon heat exposure. Nine different temperatures were chosen for testing: 300, 500, 800, 900, 1000, 1100, 1200, 1300 and 1400°C. The evolution of CS and FS in SCBF samples in correlation with the temperature is given in Fig. 2.

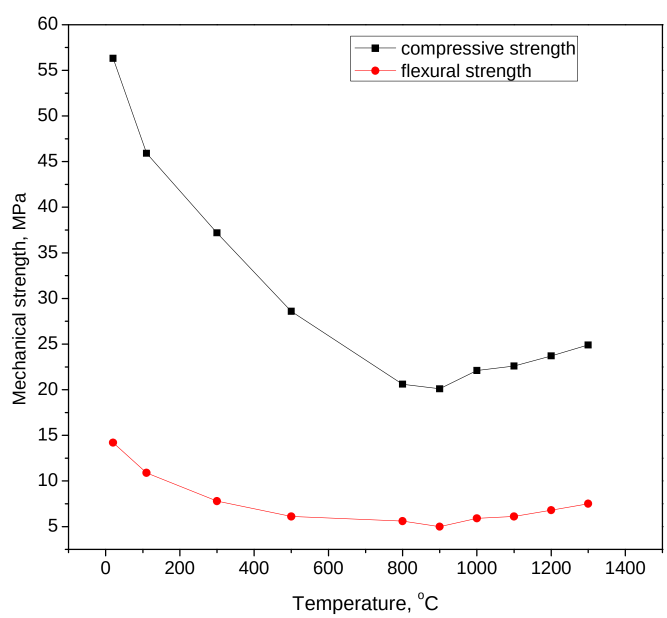

Fig. 2. Compressive and flexural strength evolution in SCBF as a function of temperature.

The SCBF compressive strength achieved at ambient temperature was 56.3 MPa, while the flexural strength was 14.2 MPa. The evolution of CS and FS during drying period from 20 to 110°C showed significant decrease over the strengths at ambient temperature. This can be attributed to the evaporation of free water that leads to increase in friction between failure planes and thermal mismatch between concrete componential materials. At 300°C, the CS and FS are affected by the temperature, decreasing to approximately two thirds of initial values at ambient temperature. During 500-800°C interval, the possible chemical transformations include decomposition of the cementing compounds (calcium aluminates and alumina hydrates). These changes usually affect the volume occupied by cementitious products and when they are combined with the weakened cohesion between the mixture constituents, induced by different expansions of componential materials, a net of micro cracks develops within the concrete mass. This consequently causes the degradation of the strength results. The lowest strength value was recorded for sample that was thermally treated at 800°C. Due to the dehydration and decomposition of cementitious products the hydraulic bonds in concrete are being weakened, reaching the lowest point at 800°C. Exposure of a concrete to higher temperatures generally causes more chemo-physical transformations to take place, like for example re-crystallization of new compounds, and additional expansions or shrinkage between the concrete constituents. Namely, hydraulic bond which primary existed between cementitious products exceeds into ceramic bond which eventually ends with sintering process. Therefore, during 800-1400°C interval a slight increase in the strengths appeared. The CS value obtained at 1400°C was 24.9 MPa and the FS at the same temperature was 7.5 MPa.

The accumulative pore volume (P) and mean pore diameter (MPD) of SCBF specimens recorded at different exposure temperatures are given in Fig.3.

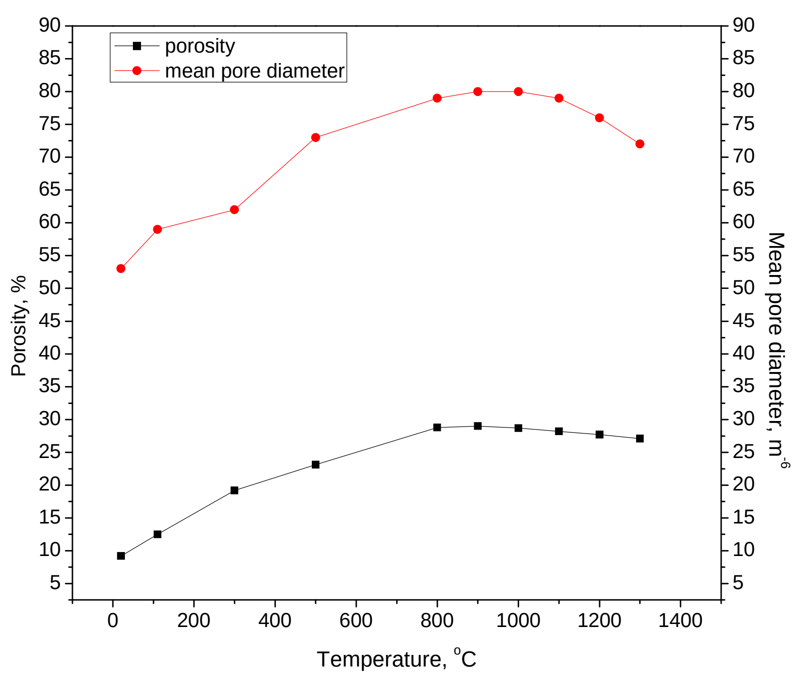

Fig. 3. Porosity and mean pore diameter evolution as a function of temperature.

The initial value of the porosity of the SCBF at 20°C was 9.2 %. After thermal treatment at 1400°C the porosity ascended to 27.1 %. Estimated value for MPD at ambient temperature was 53.0 m^{-6}. At 1400°C, MPD was higher than initial one by being 72.0 m^{-6}. However, the highest MPD value was obtained in interval 800-1000°C: 80.0 m^{-6}; while P reached 29 %. Exposing SCBF samples to temperatures up to 500°C resulted in an obvious increase of pore volume and mean pore diameter. Exposing the SCBF samples to 800°C and temperatures above resulted in the opposite effect on the specimens total pore volume. It can be concluded that the concrete with incorporated activated ash shows reduced volume of pores and smaller MPD prior to high temperature exposure as well as after exposure in comparison with concrete without addition of ash [13, 14]. Therefore, in the SCBF the ash particles had role of micro filler. Above 1000°C, the crystallization of calcium aluminates and subsequent consolidation of newly formed crystals are taking place in the concrete. The crystals are filling out voids and micro-cracks. This also induces the increase in mechanical strengths and contributes to materials resistance to deterioration. These high-temperature processes are initiation to sintering. The sintering takes place at highest temperatures and improves the properties of the material by making the structure more compact. Therefore, significant shrinkage of pores, closing of the micro-voids and reduction of porosity values are expected to occur at temperatures above 1400°C in investigated concrete. However, during 1300-1400°C interval a more prompt increase in strengths and decrease in P and MPD are noticed which can be correlated to the effect of early sintering process. These effects can be attributed to the increased ash reactivity due to the mechanical activation and the consequent influence it has on the decreasing of the sintering temperature and speeding up the sintering rate.

The SCBF concrete showed exquisite thermal resistance. SCBF sample showed refractoriness as high as 1710°C (32 SK). Refractoriness under load of 0.2 MPa expressed as temperature of softening-initiation/end-of-softening, i.e. T_a/T_e was 1430/1560°C for SCBF. Therefore, the "recycled" concrete answered thermal stability request for the standard casTab.s. High refractoriness of SCBF was induced by additional content of alumina in the concrete composition which originated from the fly ash (alumina content in the ash was as high as 59.95 %). The Fe oxide content in SCBF was low (all components contained low Fe_2O_3 content), which is important because Fe_2O_3 is causative agent for production of solid solutions. The ability of the ash based concrete to sustain exposure to elevated temperature and to match mechanical characteristics, temperature resistance and stability of standard refractory concrete is also endorsed by presence of the additional content of mineral compounds with high melting point - mullite and cristobalite originating from the fly ash [13, 14].

The SEM micrograph of a characteristic grain from the fractured original SCBF sample is given in Fig. 4.

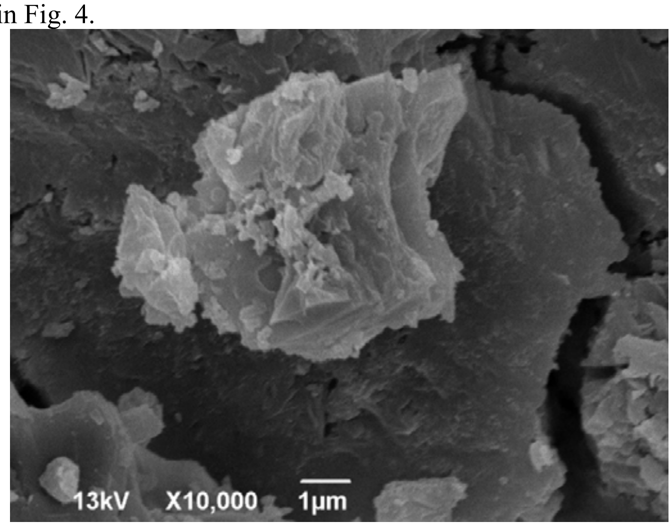

Fig. 4. SEM microphotograph of a characteristic grain in the SCBF sample.

The SCBF refractory shotcrete is a heterogeneous and complex multiphase material whose structure includes aggregate and filler particles, the cement paste matrix, and the interfacial transition zone between aggregate grains and cement paste, as it can be seen in the Fig. 4. The size of aggregate grains ranges from the micrometre scale to the several millimeters scale. In the SCBF sample, the activated ash particles are incorporated both in cement matrix and inter-aggregate zone taking over the role of filler. Besides cement paste and fine and coarse aggregates, with a range of sizes and shapes, crack structures and pores of various sizes were also noticed. The structure cracks and pores in shotcrete strongly influence its properties. Their structure is related to the original packing of the cement, fly ash used as microfiller, and the aggregate particles, to the water-to-solids ratio, etc. Ultra-fine ash particles helped in more effective packing of the structure making it more compact, and they filled out the voids left in inter-aggregate space and cement-aggregate zone. More compact structure of the SCBF shotcrete provided higher mechanical strengths, as it was previously concluded. Bauxite, chamotte, refractory cement, and fly ash appear to be thermally compatible as componential materials, since the concrete structure stayed compact without visible delaminations or grouping and consequent detachments of the component particles after firing at 1400°C.
The fractal method analysis was applied on a complex grain given in the microphotograph in Fig. 4. The first step in the procedure was to purify the SEM microphotograph and to make it free of noise and optical “mist” which will eventually produce a sharper image. Afterwards the grain is extracted out of background and placed in to a tiny frame (Fig. 5.).

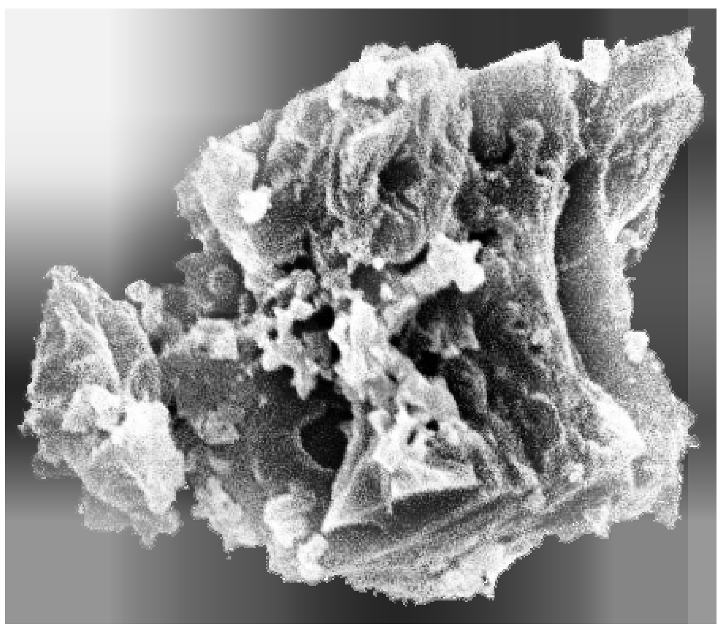

Fig. 5. The SEM microphotograph of the grain from Fig. 4. refined by means of the electronic image editor.

The electronic image that was obtained in the described manner conveys enough information to have acceptable 3D reconstruction with accurate measurements (Fig 6).

Afterwards, the 3D reconstruction is cut by family of planes parallel to xz-plane and to yz-plane in order to get profilegrams of the surface of the investigated grain. The set of three profilegrams lying in the planes parallel to xz-plane is shown in Fig. 7. The orthogonal counterparts, which are parallel to yz-plane, look similar. Both reconstruction and profilegrams exhibit high roughness degree, while the individual profilegram curves show typical almost-self-similar property characteristic for natural fractal surfaces (rocks, Earth relief, Brownian motion, chaotic dynamics etc.)

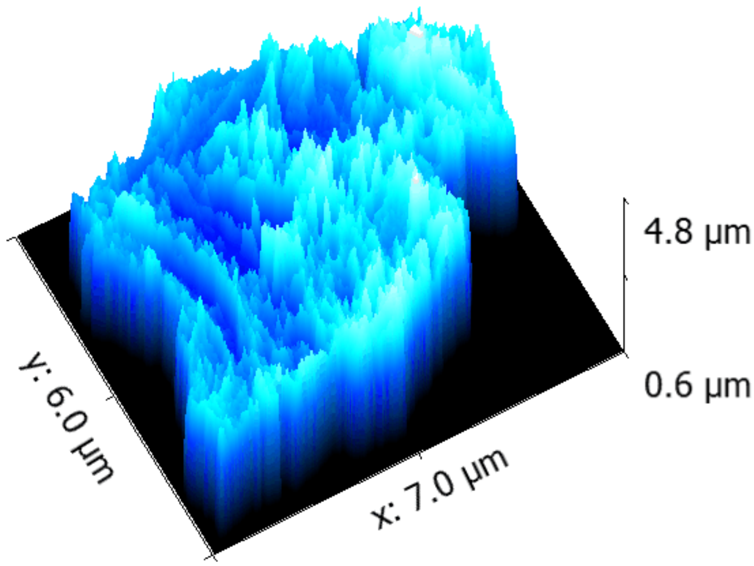

Fig. 6. The 3D reconstruction of the grain from the Fig.4 and Fig.5.

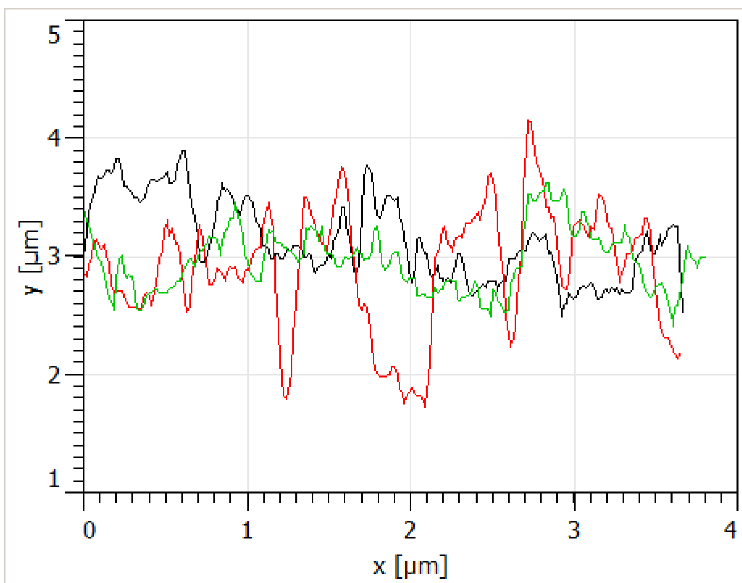

Fig. 7. Three parallel profilegrams (in x-direction) showing the degree of roughness of grain surface.

The next step was the extraction of the grain contour (Fig.8.) and application of the Richardson's "variable yardstick" method according to the formula:

$$L(r) = K\,r^{1-FD} \tag{1}$$

Where: FD is fractal dimension that ought to be determined; L(r) is the length of the grain contour circumference measured by the (variable) stride r of a yardstick.

Theoretically, if the contour is a mathematical fractal, it would hold $\lim_{r\to 0} L(r) = +\infty$, i.e., the fractal should have infinite boundary length. However, a material can not be ideal fractal, it only might be closer to fractal geometry than to smooth Euclidean geometry. Therefore, the investigated grain contour can have only an approximate fractal dimension that can be extracted from the Eq. (1) as being incorporated in linear function $\log L(r) = \log K + (1 - FD)\log r$, as the factor $1-FD$.

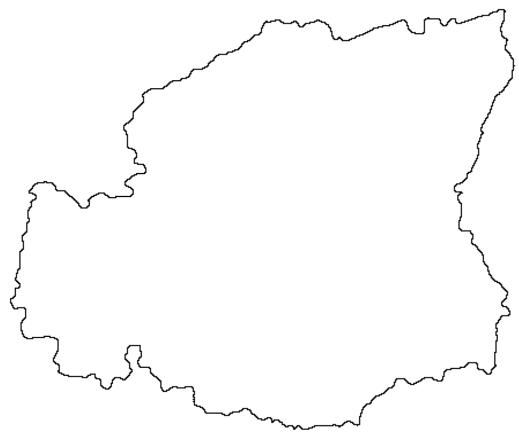

Fig. 8. The contour of the investigated grain.

The thirteen measurements were performed, and the results are presented in Fig. 9 and 10. The Fig. 9. is a log-log diagram showing linear fitting of the logs of measurements $(\log r,\ \log L(r_i))$, $i = 1, 2, ..., 13$. The obtained fractal dimension is FD =1.08386.

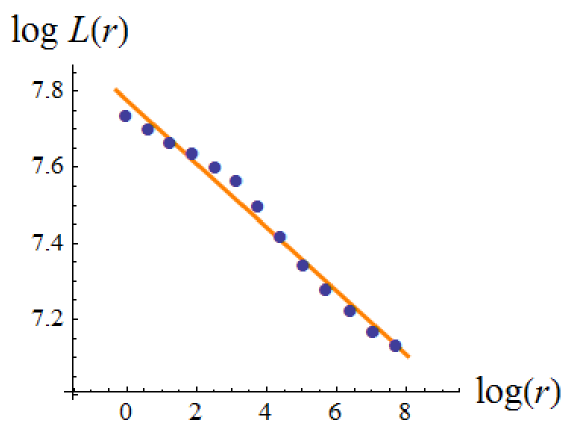

Fig. 9. Richardson global diagram.

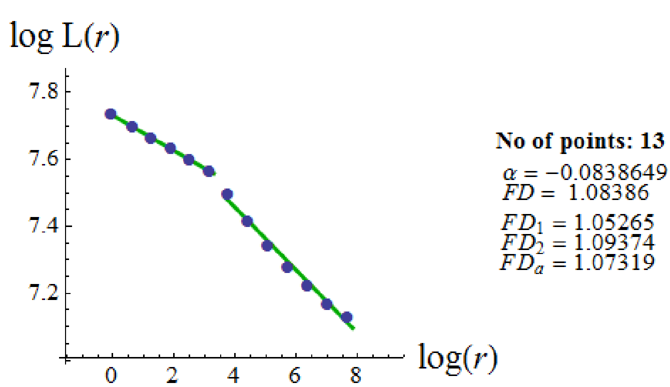

Fig. 10. Differentiation between textured (upper part) and structured (lower part) aspect of grain contour.

Following Kaye [51], many micro-particles have two fractality aspects: textured and structured. Textured fractal causes the upper part of the log-log data (Fig. 10.) while structured aspect yields the lower part of the same data. This is why two different slopes linear fit appear, the slope of textured part of data (and fractal dimension) is FD_1=1.05265, while the structured part of data has slightly bigger slope (fractal dimension) is FD_2=1.09374. The average dimension is thus FD_a=1.07319.

Regarding the fractality of the surface, things are much different. The dimension is expected to be much bigger comparing to slim FD of the contour. It is usual to use Fast Fourier Transform of 2D picture data (Fig. 11.) as an introduction test. Here, the modulus of the complex Fourier coefficient which is proportional to the square root of the power spectrum density function is calculated. The four windowing functions are used, and the output spectra are displayed on Fig 11. The window functions are:

Nutall: $w(x) = 0.355768 - 0.487396\cos 2\pi x + 0.144232\cos 4\pi x - 0.012604\cos 6\pi x$ (2)

Welch: $w(x) = 4x(1-x)$ (3)

Lanczos: $w(x) = \operatorname{sinc}\pi(2x-1)$ (4)

Hann: $w(x) = (1-\cos 2\pi x)/2$ (5)

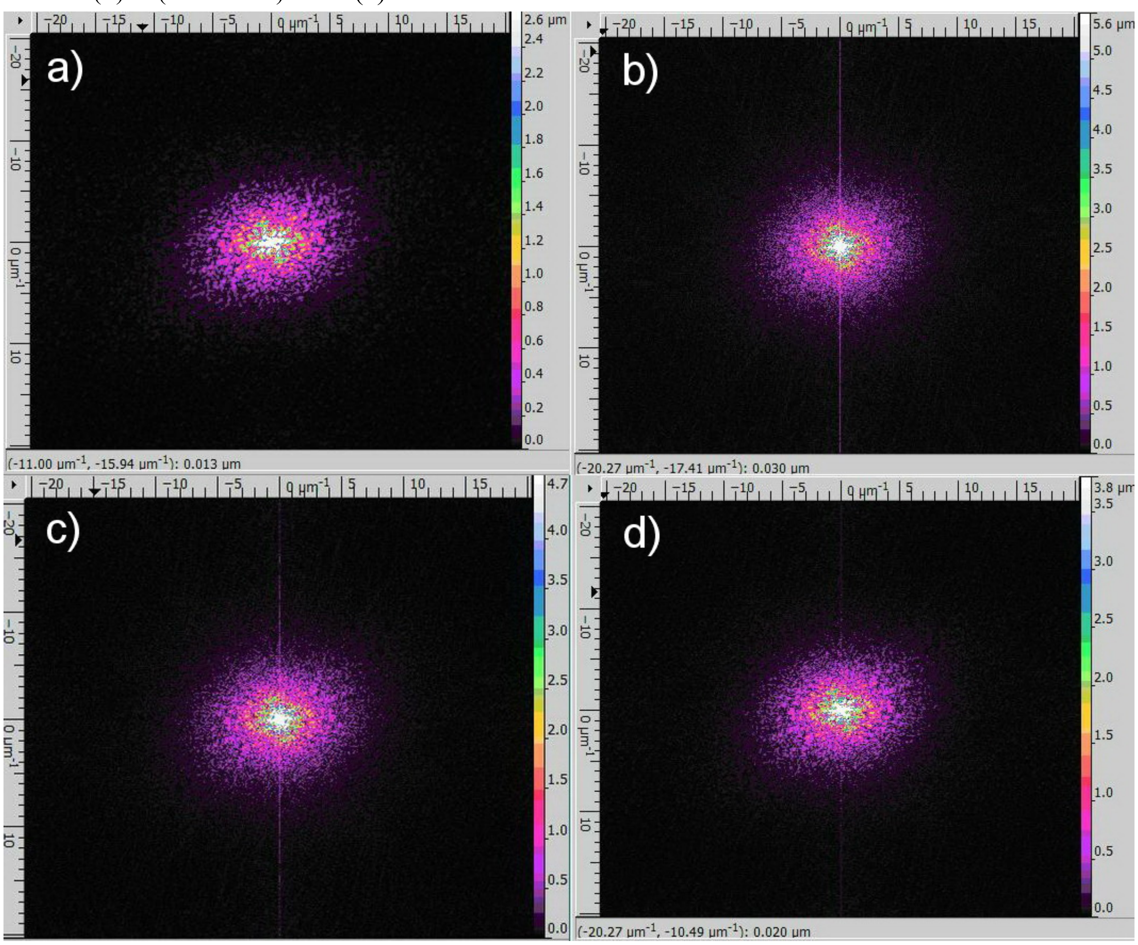

Fig. 11. Discrete Fourier Transformation of 2D grain data: a) Nutall; b) Welch; c) Lanczos; d) Hann.

Finally, the direct estimation of the grain surface fractal dimension is done using four different methods (Fig. 12.-15.): a) Partitioning (variance method) which is based on the scale dependence of the variance of fractional Brownian motion; b) Triangulation method is the variant of the box-counting method based on triangulation of the surface; c) Cube counting method also uses the box-counting algorithm with cubic fragments superimposed on the surface; and d) Power spectrum method is based on the power spectrum dependence of fractional Brownian motion.

The results are FDa=2.48, FDb=2.36, FDc=2.30, and FDd=2.41. Therefore, the average surface dimension is FD=2.3875.

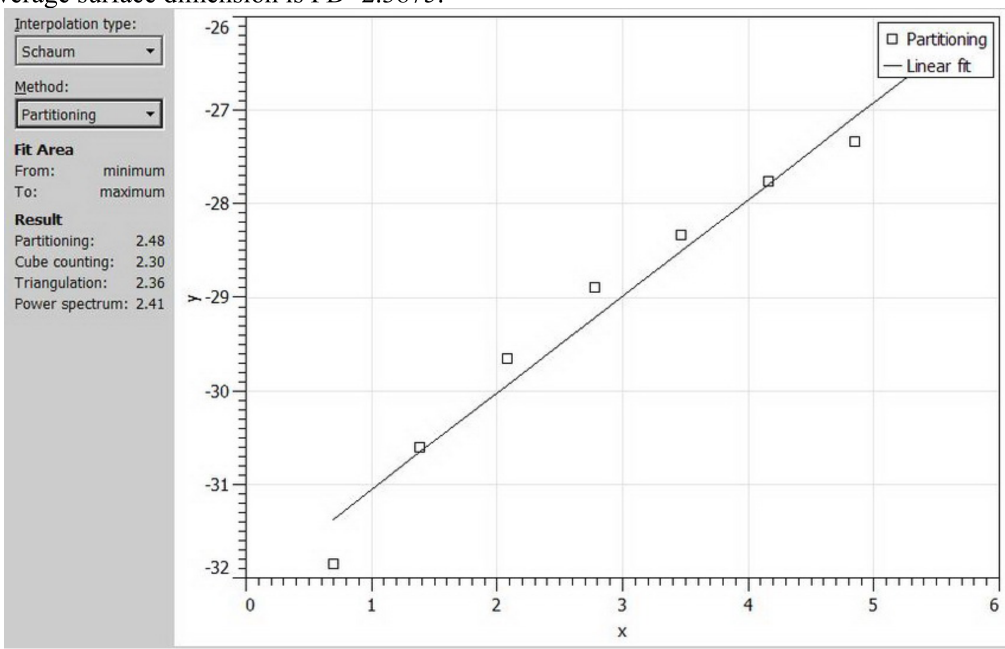

Fig. 12. Determination of the surface fractal dimension by partitioning.

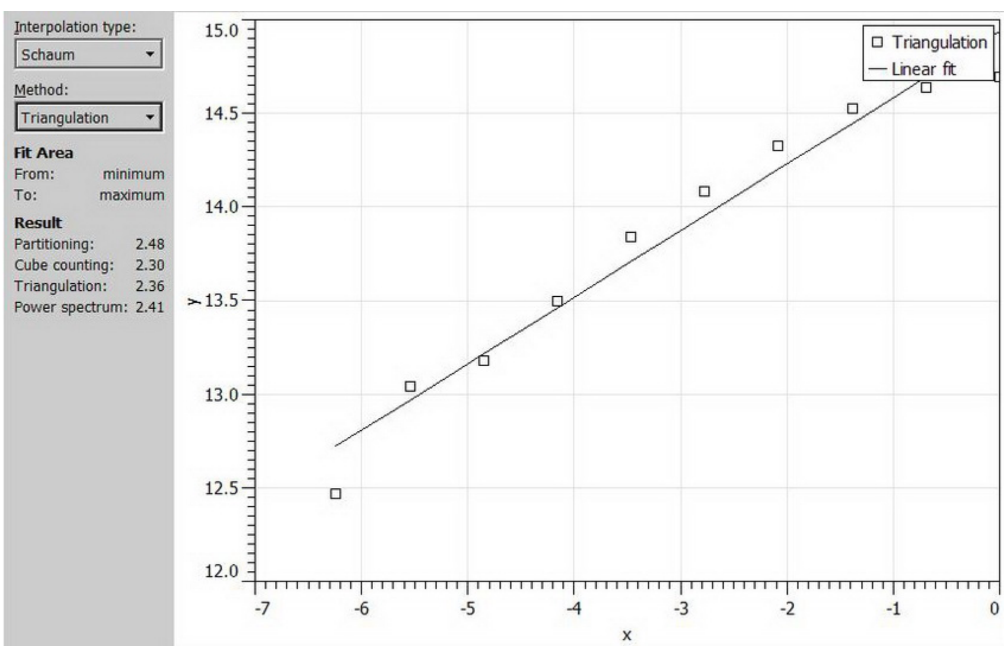

Fig. 13. Determination of the surface fractal dimension by triangulation.

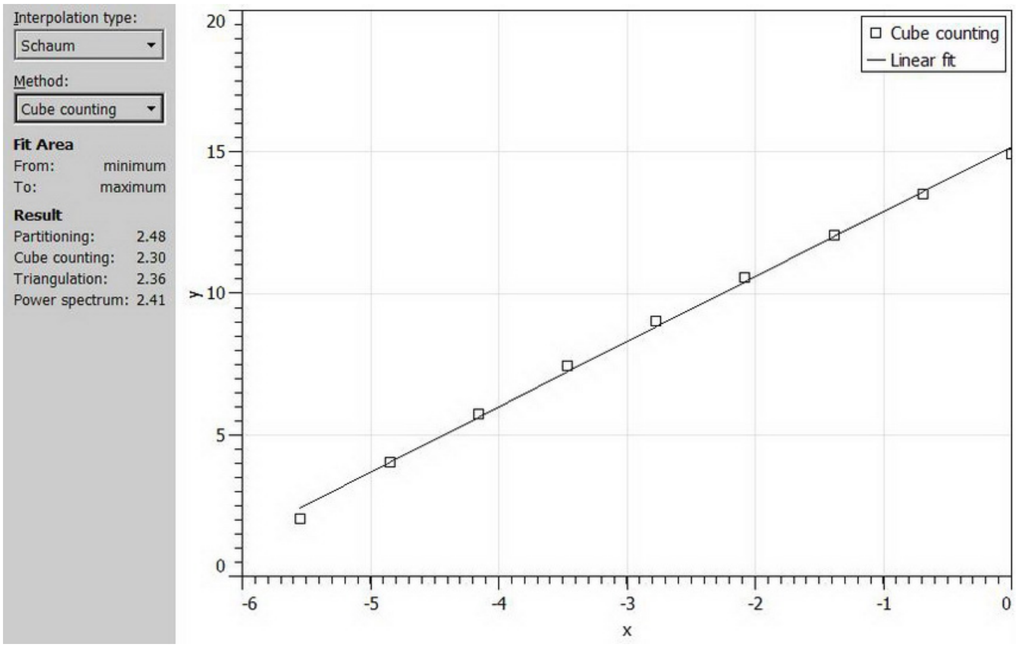

Fig. 14. Determination of the surface fractal dimension by box counting.

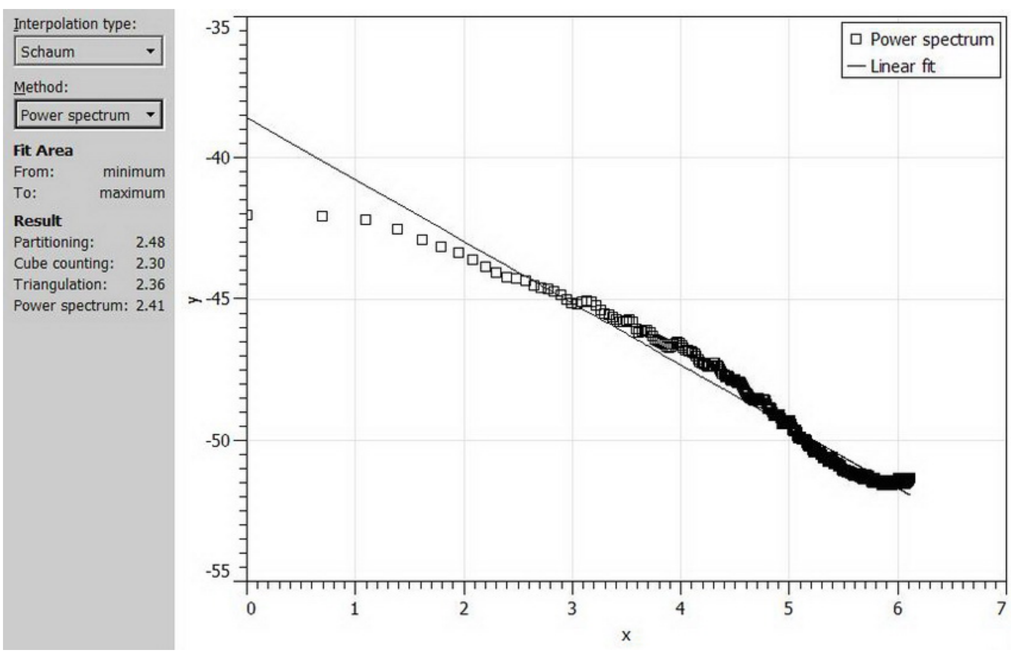

Fig. 15. Determination of the surface fractal dimension by power spectrum.

5. Fractal analysis survey

The difference between the textured fractal dimension FD_1=1.05265 and the structured dimension FD_2=1.09374 was noticed. The first dimension is the result of the number of cells containing the contour covered with a network with side length of 0.00308642 μm to 0.0745228 μm, which may represent only very tinny details of the contour while the structured dimension is the result of the network that ranges from 0.136742 μm to 6.92037μm which corresponds to bigger details.

The refractory bauxite concrete surface is more irregular than the contour itself. At first sight it may look contradictory, but this steamed is correct if it is accepted that one more dimension gives another dimension of freedom for physical material to escape the order imposed by crystal structure. So, the FFT analysis reveals expected results. For all windowing function, the bunch of frequencies occurred, clearly representing high irregularity of the surface. All four dimension estimations confirm this notice and the obtained average fractal dimension of the grain surface is FD = 2.3875.

6. Conclusion

The experimental refractory concrete SCBF based on reapplied waste raw material, i.e. fly ash was successfully produced. The SCBF physical, mechanical and thermal characteristics studied with support of SEM and fractal analysis gave results and conclusions listed below.

The contribution of the activated ash to the physical and mechanical properties of SCBF was more efficient at higher temperatures than at ambient temperature. The ash replacement in SCBF added to the degradation resistance by providing extra componential material (reactive SiO_2 and Al_2O_3) for formation and/or re-crystallization of mineral compounds that are able to sustain negative influence of temperature and to preserve mechanical strengths. Activated ash particles improved packing of the SCBF microstructure leaving a composite matrix with less structural voids in comparison to standard refractory concrete. The ash showed thermal compatibility with other applied concrete components. The sintering of the SCBF concrete began at temperatures above 1300°C as the increase in strength values and the decrease in porosity indicated. The thermal deterioration of the SCBF is not expected to occur below 1700°C. The recycled ash concrete exhibited properties that meet the requirements for the standard case, which proves it suitable for use in severe conditions.

The fractal analysis gave fruitful manipulative data concerning fractal dimension of the typical refractory bauxite concrete grain contour, the textured part of the contour and its structured part. The surface dimension is highly important in understanding many physical processes that take place in the concrete bulk. The average value of fractal dimension of the refractory concrete SCBF determined in this investigation was FD = 2.3875 and this value can be referred to in all global calculations, like for example the fluid speed for fluids flowing through the channel made of /insulated with this concrete.

7. Acknowledgements

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Садржај: *Топографска анализа која се спроводи помоћу фрактала и употребљава у објашњењу микроструктуре и механичких карактеристика композитних материјала до сада није довољно изучавана. Ово истраживање предлаже нови метод прорачуна и његову примену у триболошкој анализи површина узорака рефракторног бокситног бетона. Фрактална димензија, профилеграми и Fast Fourier transform метода су употребљени и то применом одговарајућег рачунарског програма, а у зависности од примењене скале прорачуна и, такође, нумерички у зависности од хоризонталних* *линија које пресецa испитивани профил. Такође, Richardson-ова метода и Kaye-ова модификација су коришћене како би се распознао текстурални и структурни аспект геометрије зрна. Изучавана зависност фракталне димензије и посматраних кривих је, такође, и математички формулисана. Микроструктурна испитивања су обављена помоћу скенинг електронског микроскопа. Употребом фракталног прорачуна контактних површина између зрна направљена је реконструкција микроструктуре при томе објашњавајући облике зрна и интергрануларне контакте. Добијени резултати су показали да је фрактална анализа контактних површина различитог облика била изузетно значајна за прогнозу понашања бетона. Нови методолошки приступ проучавању својстава рефракторних бетона је успешно заснован, као резултат уводећи фракталну идентификацију као нов начин евалуације својстава композитних материјала.*

Кључне речи: *ватростални материјали; механичка чврстоћа; синтеровање; топографска анализа површина; фрактална димензија; фрактална површина.*