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# Structural and acoustic investigation of the quality and degradation processes of electrotechnical insulator porcelain under compressive stress

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The paper presents the results of microscopic, ultrasonic and acoustic emission (AE) investigation of samples before and after their exposure to compressive stresses. The object of the study were specimens made of aluminous porcelain, 120 type. This material finds wide application in electrotechnical engineering for the production of reliable insulating elements. Investigation of the degradation processes of this type of materials is particularly important. On the basis of AE measurements of compressed samples the successive stages of structure degradation were distinguished. Complex microscopic analysis enabled to specify the processes of the gradual growth of microcracks and decohesion of the ceramic material. Great similarity between the appearing effects and the ageing processes occurring in a structure of exploited insulators, made of material of this type, was observed. The presented method can be used to investigate the progress of ageing processes in ceramic insulating elements operating on overhead power lines.

## 1. Introduction

Since the nineteen-sixties aluminous porcelain of 120 type has found wide application in the production of reliable insulating elements, such as line and station insulators of medium and high voltage lines as well as hollow insulators [1, 2]. A tendency is observed to reduce the production of the quartz porcelain C 110 to replace it by aluminous materials, e.g. in the case of station bushings. This results not only from the present requirements related to short-term mechanical strength. A more important problem is to ensure the reliability of supply which is connected with the durability, i.e. the long-term mechanical strength of the ceramic material. First of all, the estimation of the operating life of the material is connected with the analysis of the origin and the development of the ageing processes [3]. The essence of the process of ageing is the gradual propagation of the already existing microcracks and the formation of new ones under the influence of the mechanical stresses present in the material. They represent the sum of internal stresses and stresses induced by external factors. The internal stresses are the consequence of the technological production processes, in particular the last stage of firing, i.e. cooling. Then significant mechanical stresses are formed: on the micro-scale – on the grain boundaries of quartz and the glassy matrix; on the mezo-scale – resulting from textural anisotropy; stresses on the macro scale between the internal and the external areas of the insulator rod, induced by the temperature gradient at cooling, and intentional compressive stresses on the boundary: body – glaze. An insulator in operation is subjected also to considerable exploitation – static stresses, and additionally – attaining up to 22% of their values – dynamic loads deriving from the conductor vibrations [4]. These stresses when added to the intrinsic ones, accelerate the ageing processes. An additional factor contributing to the propagation of microcracks are the temperature changes in the body, attaining within one day even as much as 45°C [3]. In the case of insulators of the older generation long lasting periods of severe frost have a particularly destructive influence on the material. They were responsible for sudden increase of failures during the severe winter of 1986/87 [5, 6].

Nevertheless, the most essential factor responsible for the gradual degradation of the electroceramics parameters are the local stresses occurring on the boundaries of grains and phases, and the alien inclusions in the ceramic body. The stresses in the micro areas exist in a brittle medium. The only method of their relaxation is the expansion of the already existing or formation of a new microcrack. The relaxation is thus connected with the reduction of the strength of the material. The insulator in exploitation, however, is under constant external load. The progressing development of microcracks causes gradual decrease of the cross-section area of the rod, which actually transmits this load. Consequently, the internal stresses responsible for the permanent growth of the microcracks are retained.

As it was shown proved by Sjöborg [7], a evident increase in the propagation of cracks takes place at external load of the value of about 60% of the destructive stress. This necessitates the application of appropriate safety factors when insulators are loaded under operation conditions. The actual load, when taking into consideration rime and vibration caused by wind, cannot exceed 1/3 of the nominal value, which is regulated by the standards [8, 9]. An additional problem is the intensification of the ageing processes in the case where technological defects occur in the material, especially textural defects and inclusions. Moderate resistance to the ageing processes and a relatively frequent occurrence of defects in the material of 120 type of older generation are the cause of serious economic consequences. The operating life of insulators made from electrotechnical porcelain of this type in most cases does not exceed 30 years [3, 5, 6]. Figures 1 and 2 present the data collected on domestic high voltage lines for insulators produced after the year 1970 using C 120 material.

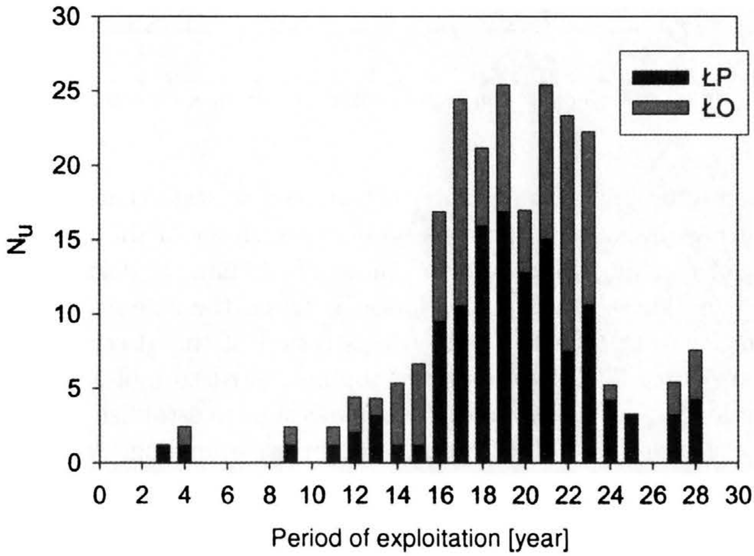


FIGURE 1. Operating life of insulators, which underwent breakdown in the tension sets – above and marked gray, and suspension sets – below and marked black [6].

The aim of the present study was the investigation of the effects of structure degradation under the influence of increasing compressive load. These effects, as it has been found, have a similar character to those which develop in the material as a result of long-term ageing processes. Slow loading of the specimens causes a gradual increase of stresses and cracks which enables their registration by the microscopic and ultrasonic methods.

To monitor the degradation processes the technique of acoustic emission was used. This method is suitable for the investigation of the destruction of ceramic materials, because due to the fact that origin and growth of microcracks belong to the main sources of AE signals. Examination of alumino-

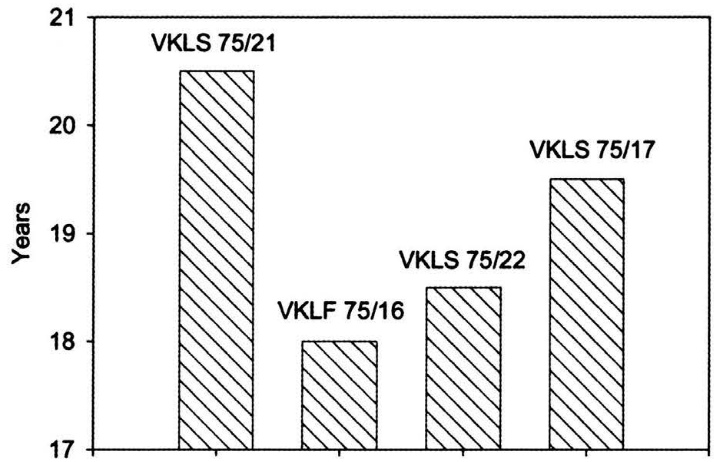


FIGURE 2. Mean operating life of broken insulators of different type [6].

silicate and alundum ceramic materials enabled to state that the sum of AE events during the lasting period is a good descriptor of the intensity of the processes of cracking which are the cause of mechanical degradation of the material [10]. There exists a correlation between the rate of the increase of cracks and the rate of AE events. Registration of this descriptor allows to monitor the process of destruction of the microstructure of a ceramic material under load. The subject of the paper was thus to establish the correlation between the progress of the external compressive loading, AE activity and changes in the microstructure of aluminous porcelain.

## 2. Ultrasonic investigation

Specimens of 120 type porcelain to be examined were obtained using a technology typical for the production of long-rod ceramic insulators. The plastic method of forming and a large chamber furnace for firing the elements having the shape of rolls with the diameter $\Phi = 8\,\mathrm{mm}$ were used. For investigations a group of samples with the length $l = 9\,\mathrm{mm}$ was cut from the rolls. Both frontal planes were polished to obtain plane and parallel surfaces with the accuracy of 0.1 mm. Ultrasonic measurements were carried out on a set specially constructed for the investigation of ceramic elements, including the long-rod insulators [11, 12]. The theoretical and practical description of the method of ultrasonic measurements was presented in [13]. The measuring set comprised a sending-receiving modulus, a digital oscilloscope Tektronix TDS 210, a mechanical system of co-axial holding down the transducers to the samples and piezoelectric ultrasonic heads for longitudinal and transversal waves. The sending-receiving module constructed at the Institute of Fundamental Technological Research of the Polish Academy of Sciences enables smooth regulation of the excitation amplitude of the sending transducer within the range $20 \div 200$ V. Regulation of the delay of the start of time base enables precise registration of the time of the wave transition through the sample. The measurement of the pulse amplitude and the time of the wave propagation is performed by digital method – the accuracy of the readout of time is $\pm 5$ ns. The ultrasonic heads used in the experimentation operated within the frequency range $4 \div 6$ MHz. The measurements were carried out on a group of 5 randomly chosen samples from the prepared specimens. The results are listed in Table 1, together with the parameters typical for materials of 120 type from long-rod insulators. The values of the elasticity coefficients were obtained on the basis of known relations [13].

TABLE 1. Results of the samples investigations and typical parameters of materials of 120 type from long-rod insulators.

| **Parameter** – symbol and unit | | **Examined samples** | **Typical insulator material C 120** |
|---|---|---|---|
| Apparent density | $\rho$ [g/cm$^3$] | 2.44 | $2.3 \div 2.6$ |
| Young's modulus | $E$ [GPa] | $92 \div 93.5$ | $70 \div 85$ |
| Poisson ratio | $\nu$ [–] | 0.23 | 0.23 |
| Velocity of longitudinal waves | $c_L$ [m/s] | $6640 \div 6670$ | $5400 \div 6200$ |
| Velocity of transversal waves | $c_T$ [m/s] | $3920 \div 3940$ | $3200 \div 3700$ |
| Attenuation coefficient | $\alpha$ [dB/cm] | $-1.1 \div -1.6$ | $-1 \div -4$ |

The rather small dispersion of the registered acoustic parameters and Young's elastic modulus for the series of the examined samples is the indicator of high homogeneity of the material. This refers both to the specimens and to the group selected for investigation. The calculated parameters correspond to the standard requirements for aluminous porcelain of 120 type: the density – at least $2.30\,\mathrm{g/cm^3}$, and Young's modulus – above 80 GPa [1, 2]. At the same time it was found that the measured parameters exceed the ones registered for materials of the same type but originated from insulators. This results from the known dependence of the material properties on the size of the object. Small samples, specially made for the investigation, show as a rule better properties than large elements. Long–rod insulators of much more complex production technology (different parameters of forming, drying and firing) contain material of worse density and a greater number of internal defects. The dispersion of the material properties within the examined group of objects and the particular insulators is also much greater.

The ultrasonic investigation comprised also samples subjected to smaller compressive stresses – $240 \div 260$ MPa ($12 \div 13$ kN) and subcritical loading – about 400 MPa (20 kN). In both cases the increase of attenuation of the sample material was registered. Smaller stress resulted in slight decrease of the velocities of propagation of the longitudinal and transversal waves. The amplitude coefficient of attenuation increased to values in the range $-2.2 \div -7.8$ dB/cm. This corresponds to values recorded for insulator materials with medium advanced ageing processes. This effect is connected with the appearance of structural defects. These are most often the separation of the grains of the crystal phases from the matrix and microcracks usually adjacent to the quartz grains, which is described in details in Section 4.

The defects in material being the effect of the compressive subcritical stresses of the order of 400 MPa caused a distinct decrease of velocities of propagation of the longitudinal and transversal waves in the samples. Apart from the decrease of the values $c_L$ and $c_T$ by about 200 m/s, the dispersion of these parameters increased considerably. The amplitude coefficient of attenuation raised to the range of about $-9 \div -19$ dB/cm. Accurate measurement of the velocity and especially of attenuation of the ultrasonic waves was considerably disturbed as a result of deformation of the received signals. Several new echoes indicating the degradation of the material and the occurrence of large separations and cracks were also registered. In one case the measurement was not possible because of defects which formed a shield for the ultrasonic waves. Similar effects were registered in the case of the material of insulators with technological defects (usually of textural kind), which growth was deepened by advancement of the ageing processes [11, 12, 14].

## 3. AE monitoring in the course of samples compression

The mechanical-acoustic investigation were conducted on a two-channel measuring system. The first channel comprised the testing machine INSTRON 6025 with computer control. A specially prepared channel-die matrix was used for the coupling the AE transducer with the sample. The steel base functioned also as an acoustic wave-guide. In the measurements the lowest velocity of traverse of the testing machine – 0.01 mm/min was used. The compressive force on the sample was registered by another computer. The acoustic measurement channel contained a broad band transducer (WD PAC type, the passband $8 \div 1000$ kHz), preamplifier and AE analyzer, coupled with the computer, constructed at the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences. The time interval of registration of

AE descriptors was 4 s, with the total amplification of signals equal to 88 dB. The threshold voltage of the discrimination was 1.19 V. In order to eliminate the acoustic effects of friction against the traverse and the walls of the channel-die matrix, prior to installation the samples were covered with a few layers of Teflon foil.

Mechanical investigations combined with the registration of AE signals comprised a group of 9 samples, chosen at random. Three profiles were loaded until complete destruction occurred. In the case of three successive ones, the increase in loading was interrupted at 260 MPa (13 kN). The last three samples were loaded to a value preceding the rapid increase of AE activity connected with a process of decohesion, about 400 MPa (20 kN). Samples, which did not undergo failure, were used for ultrasonic and next for structural investigations.

The registered AE descriptors were the count rate, event rate and the energy of signal. As it has been mentioned earlier, investigation of various ceramic materials evidenced of a correlation between the rate of events and the rate of growth of cracks. The number of events describes, in turn, the intensity of the processes of cracking [10]. These dependences were confirmed by investigations of cordierite-mullite samples with the structure close to that of aluminous porcelain of 120 type [15].

Acoustic-mechanical investigation of a group of porcelain samples enabled to state a general good repeatability of the results. This was due to good homogeneity of the material of the samples, which was evidenced by the results of ultrasonic and structural investigation. The registered courses of AE descriptors revealed the presence of two stages of acoustic activity. The first comprises the range of loading from about 30 to over 180 MPa ($1.5 \div 9$ kN). For most samples this stage can be divided into two intervals. The earlier one shows maximum at the stress of about 70 MPa (3.5 kN), the latter one – at about 140 MPa (7 kN). The first stage of acoustic activity, defined as a preliminary one, corresponds to the earlier phase of the development of defects. They result from the gradual relaxation of stresses formed in material as a consequence of technological production processes. As it was evidenced by the structural investigation, presented in Section 4, these effects are similar to the development of microcracks which are the consequence of progress of the ageing processes. It should be noted, however, that the preliminary stage of acoustic emission shows, for the particular samples, considerable differences concerning, first of all, the quantity of signals of the rate of events. Figure 3 shows the typical course of the acoustic activity of the preliminary stage on the example of a sample loaded up to 260 MPa (13 kN).

After a short reduction of the acoustic activity, at the stresses of about 260 MPa , there begins the second stage lasting in principle until the sam-

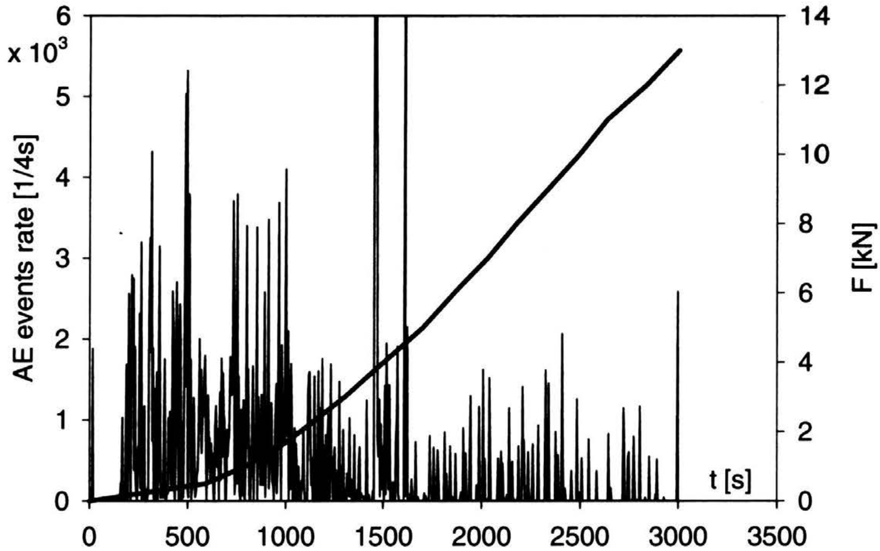


FIGURE 3. Course of the rate of AE events as a function of the compressive force. Loading of the sample was stopped at 260 MPa (13 kN).

ple destruction. This stage may be also divided into two intervals of much greater AE intensity and better repeatability than in the case of the preliminary stage. The first interval, defined as subcritical, corresponds to load within the range of about $260 \div 350$ MPa ($13 \div 17.5$ kN). The extreme AE in this interval occurs at the stress of about $280 \div 310$ MPa ($14 \div 15.5$ kN). The high level of AE in the subcritical range of loading is connected with the formation of large separations and gradual propagation of cracks towards the sample inside. It was revealed by microscopic examinations. Loading of the examined samples was interrupted before starting the second – critical interval of the acoustic activity. This enabled us to note the high level of the sample defectiveness, which was proved by a comparative study, corresponding to material degradation as a result of severe technological faults.

The last interval, showing also a high level of acoustic activity, begins at a load by some tens of megapascals (a few kilonewtons) smaller than the destructive load and lasts up to the sample becomes damaged. This interval, defined as the critical one, is characterized by a good repeatability of the level of AE signals. The extent of its occurrence, however, depends on the strength of the particular sample. The breaking stresses for three samples loaded until complete destruction were: 379.4, 384.5 and 428.9 MPa, which corresponded to the forces: 19.1, 19.3 and 21.5 kN, respectively. Figure 4 shows the course of the rate of AE events as a function of load for a sample, which was destroyed at 379.4 MPa (19.1 kN).

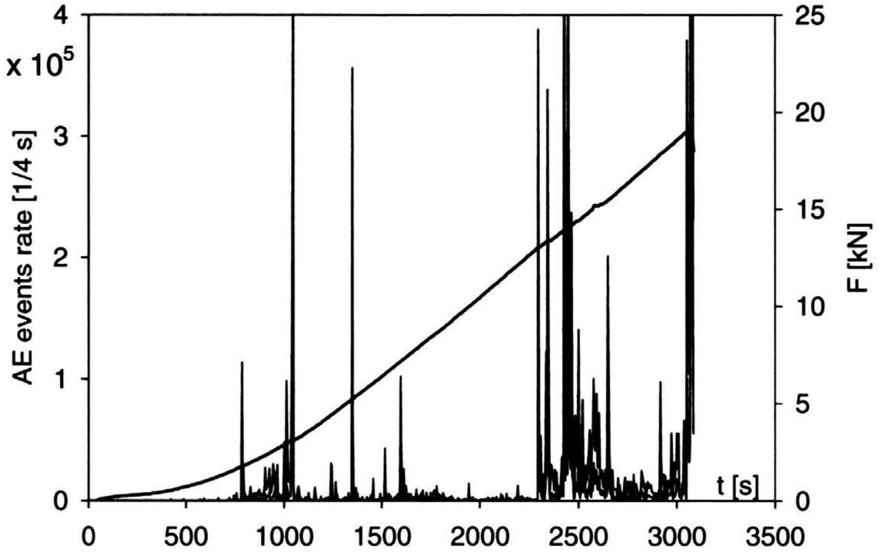


FIGURE 4. Course of the rate of AE events as a function of the compressive force for a sample which was destroyed at the load 379.4 MPa (19.1 kN).

## 4. Structural investigation of the samples

Microscopic analysis of the structure of porcelain specimens required careful preparation of the polished sections on cut pieces. The sample surface was cut into pieces with a saw disc, containing grains of 60 $\mu$m in size, became defected to a depth reaching up to 200 $\mu$m. In order to remove partially the damaged layer and to decrease the stresses created in the material, the slight etching with 5% solution of $H_2F_2$ was applied. The process was conducted for 40 minutes at room temperature. After rinsing and drying the sample was polished with a colloidal solution of silica on a fabric of 90% porosity. The polishing was made in a stabilized medium with pH = 9.3, in the presence of sodium (I) chlorate. During the process the system was cooled to 15°C. After rinsing in chemically active detergents and drying in alcohol vapors the microsections were ready for microscopic investigation. The optical microscope (MO) coupled with the computer image analyzer CLEMEX was used. The applied power of the objective ranged from $\times 10$ to $\times 20$, which corresponds to the resolution ranging from 0.3 to 0.1 $\mu$m. The measurement of the content of the particular phases and the size of grains and pores together with the statistical specification was carried out by the counting method in Nomarski intereference-phase contrast. This enabled to visualize the crystal phases and gaseous inclusions against the background of glassy matrix, as well as texture, level of homogeneity and reaction completion of raw materials. Investigation of the porosity parameters were performed in polarized reflected light (without Nomarski contrast). The microscopic analysis of the material before the mechanical-acoustic examination was carried out on five polished sections prepared after cutting of various samples. High similarity between the examined structural images was observed. The material showed good homogeneity as regards the content and the spatial distribution of the crystal phases and the gaseous inclusions. The degree of the completion of reaction of raw during firing was correct. The dominating crystal phase was mullite representing about 25% of the surface of the specimens. It occurs in the form of regular precipitates of various size, not exceeding $30\,\mu$m. The quartz grains had a rounded shape and medium dimensions, below $25\,\mu$m. Their content is not high – about 12% of the microsection area. In the polished sections a sporadic occurrence of corundum was also recorded. Its content did not exceed 0.5%. Corundum is present in the form of very bright, fine grains of characteristic elongated shape and the size below $3\,\mu$m. The glassy matrix occurs in relatively high amount – within the limit of 60 % of the microsections area. The pores are as a rule small – about $7\,\mu$m, occur merely in the amount of 1.5% and are very regularly distributed in the matrix.

Typical insulator materials of 120 type have somewhat higher contents of the crystal phases: about 30% of mullite, a dozen or so of quartz and about 1% of corundum. The consequence is a smaller amount of the glassy matrix, usually less than 50%. There should be noted, however, the higher porosity of typical aluminous materials, usually contained within $3 \div 7\%$. The analyzed material demonstrates generally better homogeneity and a smaller amount of peripheral cracks around the quartz grains, which may be due to smaller dimensions of the grains. Great homogeneity of the material of the sample, their low porosity and the minimal number of structural defects are the result of the small dimensions of the specimens. The technology of their production is much simpler than that of long-rod insulators. This refers, as it has been mentioned, to the parameters of the processes of formation, drying and firing. The material belongs to the group of high-aluminous (mullite, 120 type) porcelains with a somewhat lower than usual content of the crystal phases. Figure 5 shows the structural image of the ceramic material of the examined samples.

Detailed structural investigation comprised samples after the preliminary stage of acoustic activity (loading up to 260 MPa – 13 kN). Analysis of three samples has revealed the absence of greater stratifications. Occurrence of cracks propagating into matrix was observed only incidentally. When compared with the unloaded samples, numerous separations of the crystal grains from the matrix were registered. They occasionally dropped out during pol-

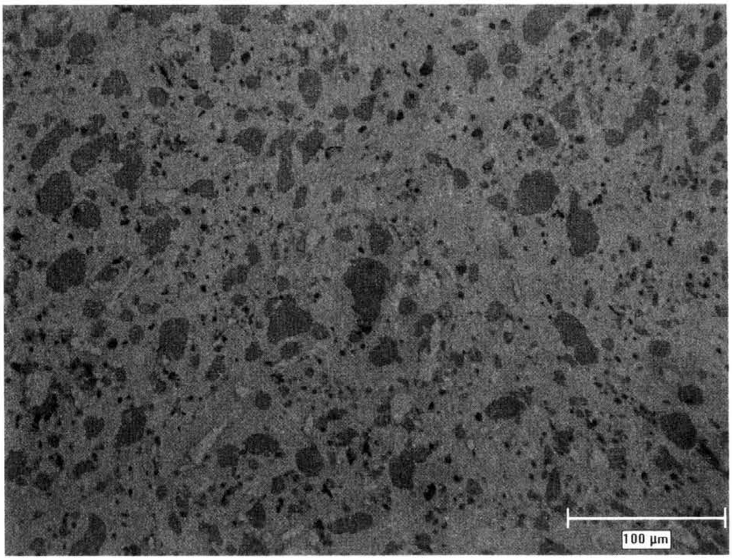


FIGURE 5. Image of the structure of the examined material, magnification 200×. Darker mullite precipitates and bright quartz grains in the grey glassy matrix are visible. Fine dark areas represent the pores.

ishing. The stress on the grain boundaries and small peripheral cracks are generated, as it has been mentioned, mainly during the process of firing, especially at the stage of cooling. They are the consequence of differences in the coefficients of thermal expansion. This relates primarily to quartz, which at the temperature 573°C undergoes polymorphic transition with the reduction of its volume by 2.4%. Also at lower temperature the quartz grains shrink faster than the glassy matrix. Particularly, large grains show weak bonds with the matrix after firing. In the case of mullite precipitates the stresses on the boundary with the matrix are much lower and the separations are rare [16]. Large precipitates of mullite, however, contain sometimes fine internal cracks as a result of the decohesion of crystallites. External loads cause the relaxation of stresses on the grain boundaries – discontinuities are formed while the existing microcracks become larger. These effects are accompanied by the acoustic emission of the preliminary stage, which is particularly well visible in Fig. 3. Thus the preliminary stage of acoustic emission corresponds to the effects of the propagation of defects of lower threshold energy, introduced at the stage of the technological processes of production. Their increase, however, is rather limited.

The defects observed in the samples subjected to loading not exceeding 260 MPa show close similarity to those observed in the material of insulators after about 20-year-long period of exploitation. Complex investigations of C120 material of long-rod post insulators from the nineteen-seventies enabled to state a generally medium high, however differentiated degree of advancement of the ageing processes [11, 12]. The differentiation in the degree of degradation of the ceramic material might have been connected with the lack of full repeatability of the technological processes, especially firing in the then used chamber furnaces. The observed reduction of the mechanical, electric and acoustic parameters was the result of a great number of small microcracks which adhered to numerous quartz grains. A definite majority of grains, especially the greater ones, became partly separated from the matrix. Unlike in the case of quartz, the peripheral cracks occurred only by a small portion of mullite precipitates. Some of them showed, however, internal cracks. This was due to the separation of large needle-like mullite crystals formed as a result of recrystallization. Only part of the cracks present around the grains pass into the glassy matrix. It was found that pores of regular shape, even it they are of relatively great dimensions, although they are centers of the concentration of stresses, do not generate cracks.

Thus the results indicate a similarity between the effects of the influence of the loads on the porcelain material during many years of exploitation of the insulators and those of the mechanical compressive load in a laboratory short-term tests. In either case there occur defects at places of internal stresses, first of all on the microscale. The quartz grains and, to a smaller extent, mullite precipitates become considerably separated from the glassy matrix. A few cracks running towards the inside of the matrix are formed. Greater precipitates of mullite, containing large needle-shaped crystals demonstrate internal cracks. With the increase of the stress acting on the sample or the lapse of time in the case of insulators operating on power lines, the described effects become greater forming long, often branched, cracks. Figure 6 presents the structural image of the material of a sample subjected to loading 260 MPa (13 kN). Figure 7 shows the structure of the insulator material after more than 20 years of exploitation.

Investigation of samples subjected to stresses in the subcritical range – up to about 400 MPa (20 kN) indicate a high degree of the material defectiveness. The grains of the crystal phases became almost completely separated from the matrix. In many places the smaller cracks combined, forming the longer ones. The cross-section of samples in the direction parallel to the compression axis have revealed a higher degree of destruction of their central part. Large cracks, branching out towards the sample inside were noticed there. Maximal branching out occurs at about 2/3 of the specimen height from the side of the surface in contact with the traverse. Cascade splittings of greater cracks can be observed there (Fig. 8).

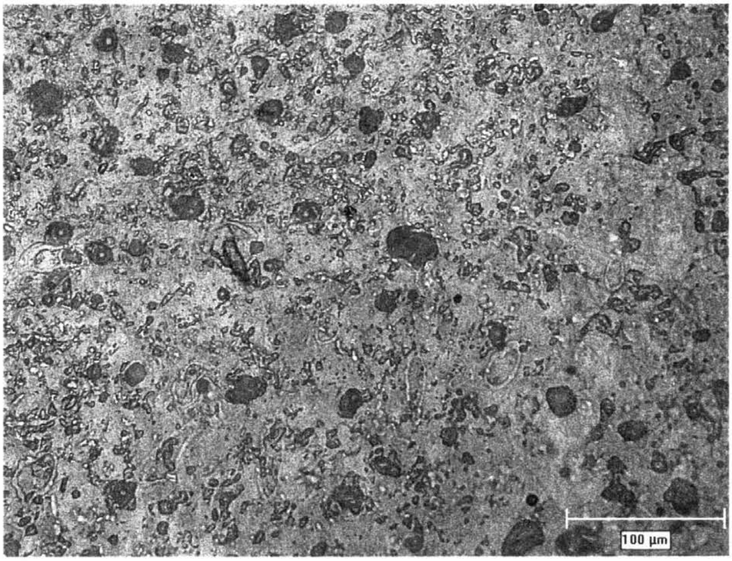


FIGURE 6. Image of the structure of aluminous material after the preliminary stage of compressive stresses, magnification 200×. There appear numerous separations of quartz grains and less often mullite precipitates from the matrix.

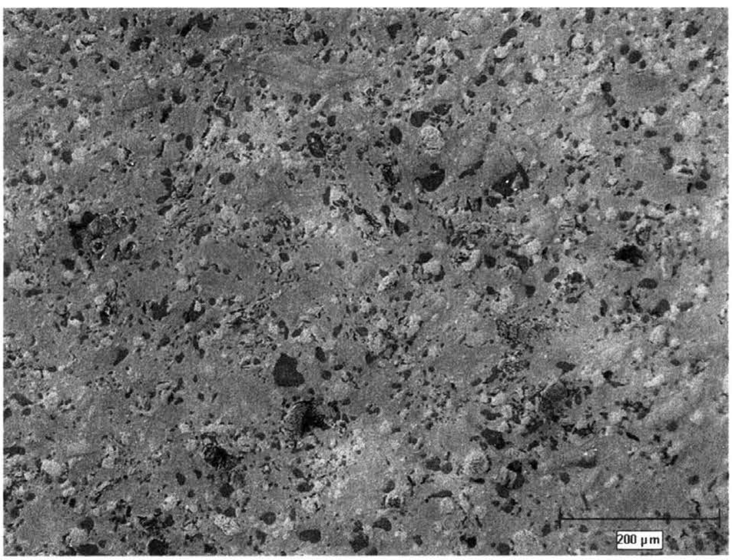


FIGURE 7. Image of the structure a material of 120 type of an insulator from the middle of the nineteen-seventies, magnification 100×. Numerous fine cracks inside and around the bright quartz grains are visible. Darker mullite precipitates also display cracks.

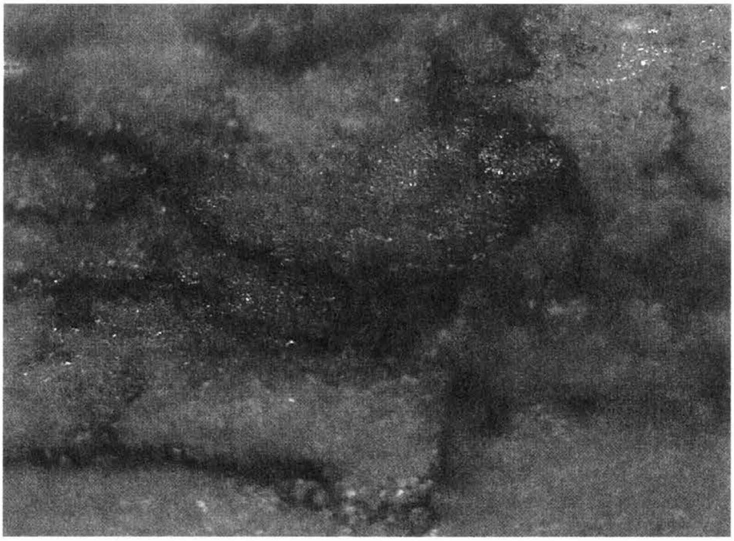

FIGURE 8. Cross-section of a sample, magnification 50×. Branched cracks in the central part of the sample are visible.

It was found that even samples with many defects do not undergo disintegration. The cracks are blocked, which is an indication of effective strengthening of the structure by the mullite phase. Propagating cracks have, as a rule, intercrystalline character, which is the consequence of the slow increase of the load (0.01 mm/min) and of phase structure of the alumino-silicate porcelain material.

The occurrence of similar, but more intensive, effects were observed in the case of the material of broken insulators, which were examined in order to establish the cause of the breakdown. Close analogy was observed in the case of objects in which already at the stage of production there occurred strong stresses on the mezo-macro and macro-scale. They were due to textural defects caused by improper operation of the vacuum press [14]. Also in the case of insulator materials some tens of years old there can be occasionally observed the development of a network of cracks responsible for the decay of the object even in the case of moderate exploitation conditions. Textural faults and inclusions brought about numerous breakdowns of insulators made in the former German Democratic Republic (KWH Sonneberg), from porcelain material of low resistance to degradation with the progress of time [5, 6]. On the other hand the insulators with high level of material defectiveness are sometimes in operation often for many years without breaking [11, 12]. This is due, among others, to the effective slowing down of the increase of cracks and structural strengthening by the mullite phase.

On the basis of the performed investigation it can be stated that the subcritical load of samples causes a similar degree of structure degradation of aluminous porcelain as in the case of technological textural defects together with advanced ageing processes. Figure 9 illustrates a catastrophic development of cracks in the middle of the rod of post insulator with a textural defect, after 20 years of exploitation.

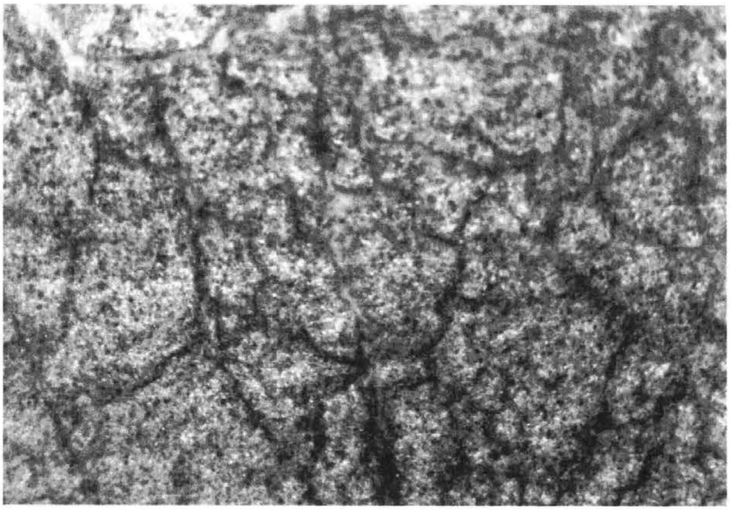

Figure 9. Image of cracks of the material of a post insulator from the year 1976 with its structure disturbed as a result of defective operation of the vacuum press, magnification 20×.

## 5. Conclusions

The phenomenon of breaking of long-rod insulators becomes more frequent since the nineteen-eighties, however, it still remains a serious economic problem. Development of methods enabling to monitor the degradation processes of electrotechnical materials may be of great importance for predicting the operating lifetime of insulators. In this study a method of investigating the ageing processes by means of mechanical-acoustic measurement on the samples of aluminous porcelain 120 type has been suggested. A close similarity has been found between the structural effects of slowly increasing compressive stresses applied to the material and the degradation processes being the result of many years of exploitation on power line. Application of the acoustic emission method enabled to distinguish two stages of material degradation, considering the clearly separated intervals of acoustic activity.

Although this effect is known and has been described in literature [15, 17], it has not been until now connected with the development of the ageing processes in ceramic materials. The conducted measurements, due to comparing them with the results of investigation of materials exposed to prolonged period of exploitation [11, 12, 14], enabled to determine such dependences.

The first stage of degradation occurs as a result of places of internal stresses present in the material, mainly at the micro-scale, generated during the manufacturing processes. The process of increase of defects has a relatively low threshold energy and they can develop already at lower stresses of sample. The process of their propagation under exploitation conditions, however, is slow and takes many years. This is mainly due to the presence of densely distributed precipitates of mullite which has high mechanical strength. Young's elasticity modulus of the mullite phase is nearly two times higher than that of the porcelain material. Hence the mullite plays the role of dispersive strengthening of the material.

The second stage of the AE activity corresponds to long lasting development of subcritical defects. The stresses developing under increasing load undergo to some extent a relaxation through local microplastic deformations. The process of decohesion is partly stopped, the microcracks are branched on the intergranular and phase boundaries. Overcoming each of these boundaries requires some definite energy. However, with sufficiently high load a rapid process of the propagation of cracks takes place which precedes the disintegration of the sample. This finds distinct reflection at the high level of AE signals. The structural effects corresponding to the second stage of AE activity have a similar character to that observed in material of fractured insulators. The structure becomes defected in a similar way as due to the textural defects after a prolonged process of cracks growth. The single cracks join together in time, and after branching out they lead to the development of a network of cracks and the destruction of the insulator.

Similar investigation will also be carried out for other ceramic materials for electrical engineering, first of all, for the corundum porcelain of 130 type. It is hoped they will contribute a great deal to the knowledge about the ageing processes of materials used in the production of such reliable elements as insulators of high and medium voltage power lines.

## Acknowledgements

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