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Prof. Jerzy Ranachowski

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THE OUTPUT OF THE FIFTY YEARS' SCIENTIFIC ACTIVITY OF PROF. DR. JERZY RANACHOWSKI

I. MALECKI

1. Introduction

Professor Jerzy Ranachowski began his research as an assistant at the Electrical Faculty of the Technical University in Wrocław under the guidance of Professor J. Skowroński.

After getting a degree in 1951, he started working at the Institute of Electrical Engineering of this University. At that time, this Institute introducing innovative technical solutions was one of the most important research institution in Poland. The international prestige of the Institute opened a chance to encounter the newest achievements of world-wide science. The research of J. Ranachowski at this Institute concerned two fields related closely to one another: the high-voltage techniques and the technology of ceramic materials. Just at the beginning of these works, he focused his attention on the application of ultrasounds to testing of ceramic materials and high-voltage electric devices. In 1956, he established a close co-operation with the Institute of Fundamental Technological Research of the Polish Academy of Sciences. His interest in the problems of acoustics was gradually increasing. In 1975, Prof. Ranachowski started to work at the latter Institute, where, besides managing a research team, he held several responsible positions; among other, deputy director of the Institute. He still continued his acoustic research as well as the study of ceramic materials and high-voltage insulating systems. Professor Ranachowski retired in 1996 but remained a creative scientist and manages a team of research and technical workers.

The scientific work and technical achievements of Prof. Ranachowski gained high recognition from the whole scientific community. This respect was expressed by appointing him full professor in 1987 as well as in the many rewards for his scientific and technical achievements. Furthermore, one should stress his considerable contribution to the development of acoustics in Poland as well as his engagement in the national and European co-operation in this research field. Professor Ranachowski is vice-president of the Committee on Acoustics of the Polish Academy of Sciences and an honorary member of the Polish Acoustical Society and has been its president since 1996. He has made a considerable contribution to the increasing co-operation of the latter society with the Federation of the Acoustical Societies of Europe (FASE) and later with the European Acoustics Association (EAA) that get through to FASE; at present, he is a member of

the EAA Council. His membership of the European Material Research Society (E-MRS) is important for the international co-operation.

The contribution of Prof. Ranachowski to the co-operation of the countries of Central and Eastern Europe in the field of acoustics and the research of ceramics should be stressed. Under his scientific and organisational leadership, varied scientific and technological conferences are held regularly in which participate specialists in acoustics and ceramics from Poland and the neighbouring countries, i.e Belorus and the Ukraine. Also, the membership of Prof. Ranachowski in the Polish Electricians Society should be mentioned; he has established the Polish Committee of Electrotechnological Materials of this society.

2. The research linking acoustics and materials technology

The research work of Prof. Ranachowski was always guided by problems arising from technological needs vital to Polish industry and power engineering. This is why his scientific achievements should be considered as a logically developing whole. The knowledge of the physicochemical properties of ceramic materials and the production of those materials nowdays is one of the crucial problems of materials technology. The achievements of Prof. Ranachowski, a brief account of which is given below, are of unique character. He belongs to the sparse scientists and technicians who are able to apply broadly the acoustic methods in materials technology. His fundamental assumption was that the indispensable condition of achieving improvement in the production of ceramic materials is the perfection of the measuring methods. Professor Ranachowski applied broadly the electric [4], magnetic [46] and microscopic methods and the X-ray analysis. He gradually became interested in the application of acoustic methods, first in the classic ones (measurements of the velocity and attenuation of ultrasound), later in the extension of those applications to surface waves (SAW) [40, 49] and to the photoacoustic spectroscopy (PAS) [24]. The most considerable achievements of Prof. Ranachowski in the last period concern the applications of the acoustic emission (AE) methods. Those works lead to new technical applications of the research results of Prof. Ranachowski. To them belong: the investigation of the mechanical properties of concrete and the application of acoustic methods to the detection of contaminations of gases and to the testing of industrial oils. The developing of acoustic methods for the study of static and dynamic processes for material engineering was an essential novelty.

The static investigations have concerned the structure and microstructure of ceramics, their mechanical, electrical and thermal properties and the dependence of those parameters on the composition of the materials and the production procedure. The dynamic investigations are aimed mainly at the time dependence of the cracking of the materials under mechanical, electrical and thermal stresses; this time dependence allows to determine "life-time" and the usefulness of ceramic materials. The measurement techniques used in those investigations are essentially different. While in the static investigations most information is provided by the microscopic and ultrasonic methods, the acoustic emission is most useful in dynamic investigations. However, static and dynamic investi-

gations supplement one another giving a complete picture of the technically important properties of the object under test.

3. The most important scientific achievements

One of the most momentous scientific achievements of Prof. Ranachowski was the comprehensive theoretical and experimental investigation of the structure of ceramic materials. The first stage of this work consisted in the improvement of the method of getting microscopic pictures of those structures and in the working out in atlas of electrotechnical porcelain [6]. Next, he worked on the electrical method of measuring the leakage and inverse currents and on the dielectric strength of ceramic materials [36]. The study of ceramic materials, and particularly of their porosity, by applying acoustic methods was scientifically and practically most fruitful [9, 11]. The starting point was the study of the investigation of the triple point of the phase equilibrium of porcelain-like materials [10]. An undoubted scientific success of Prof. Ranachowski was the finding of a correlation between the velocity of propagation of ultrasounds and their attenuation and the parameters characterising the degree and structure of the porosity of the ceramic materials of the K_2O-Al_2O_3-SiO_2 system; simultaneously, the influence of the degree of porosity on the mechanical [13] and dielectric strength of the material was determined [19]. A theoretical extension of Prof. Ranachowski's experimental work were studies on the distribution of electrical, mechanical and thermal stresses in heterogeneous materials, particularly in ceramics; this was connected with the discovery of the effect of the textural deffects on the internal stresses [5]. His work concerned also the application of the theory of complex cross-sections to porous materials with scattered enclosures [55]. His considerable achievements belong to the results of studies concerning the measurements of the critical value of the stress intensity coefficient K_{IC} [14, 54] that is a parameter adequately characterising the brittleness of ceramic materials.

The studies of Prof. Ranachowski have proved the particular usefulness of the acoustic emission method (AE) in the investigation of dynamic states. The improvement and extension of those methods has been his main task during the last years. The starting point was the monitoring of acoustic signals generated by microfractures developing in the ceramic material under the influence of a groving mechanical stress [23]; a corresponding theory has been developed [47]. It turned out that the analysis of the AE signals provides unique information about the initial stage of the structure distortions that cannot be detected by other methods. The studies of Prof. Ranachowski were aimed at the choice of appropriate descriptors of the acoustic emission signals that are essential for the effectiveness of the AE method [41, 48]. The fact that the force at which threshold AE signals appear is a linear function of the destructive force [23] paved the way for new applications of the acoustic method to the non-destructive testing of materials (NDT). Also, an important find for Prof. Ranachowski is that there exists a correlation between the activity of the AE and the variations of the conductivity and the magnetic effects in the ceramic material [32, 33]. However, two of his publications seem to be of greater importance.

The first one concerned the prediction of the "life-time" of ceramic elements, particularly of high-voltage insulators, based on the ratio between the exploitation stress and the destructive one [25]. Beside the conventional methods, Prof. Ranachowski has applied to this end the acoustic emission method. The theoretical calculations, confirmed by testing of insulators on lines of the highest voltage, were based on the Weibull's statistics.

The second publication concerned the evaluation of thermal shocks on the degradation and strength of ceramics used in electrical engineering. Professor Ranachowski studied both the effect of single strong thermal shocks (of the order of 400°C) [39] and that of periodic temperature oscillations that affect high-voltage lines [44]. In both cases, the dependence of the activity of the AE on the state of the object under test was proved. The finding that the extent of defects in the ceramic material influenced the consecutive maxima of the AE counting rate due to periodic variations of the thermo-mechanical stresses [34, 56] was of particular interest.

4. Contributions to the technological development and technical innovations

The scientific activity of Prof. Ranachowski was closely related to practical needs. It is therefore difficult to separate his scientific achievements from the technical ones. It is nevertheless worthwhile to mention which of his works have been fully used in practice, mainly in the technology of ceramic materials and in the control of electrical power systems. The practical importance of the atlas of porcelain structures has been mentioned previously. The studies of Prof. Ranachowski on the causes of breakdowns of insulator systems and the co-ordination of overload protection systems in 12 Polish power plants and substations had a broad range. These works concerned the co-ordination of insulations in high-voltage systems, connecting links, transformers and transmission lines. They have contributed significantly to the failure-free work of electrical power systems exploited in Poland.

High-voltage insulators were the object most extensively investigated by Prof. Ranachowski. His contribution to the improvement of the production of those insulators is unquestionable, but most importantly are his works for the industry of electro-ceramic materials concerning the control of the mechanical and electrical parameters of insulators. The latter works concerned also the influence of parameters of the production process and the composition of the raw material on those properties. Prof. Ranachowski worked out the fundaments of defectoscopic investigations of insulators for the detection of inner flaws and implemented those methods in the industry [1, 3, 4]. For electrical power engineering, the most important works were those concerning the determination of the degradation of insulators during their long-term work on high-voltage lines; this is important for the replacement of used up insulators. Those investigations are of great economic and social importance because of the enormous cost of renovation of high-voltage lines and the disastrous consequences of a possible breakdown. The application of the AE monitoring of the influence of periodical variable thermo-mechanical loads on the ageing of insulators was a significant progress in this field [33–35, 56]. The acoustic emission method worked out by Prof. Ranachowski was found to be particularly

useful in the study of the mechanism of ageing and the "life-time" of ceramic materials. Prof. Ranachowski worked out the methods of investigation of insulating materials and a device that also enables the investigation of insulators in the place of their work. This method received wide acceptance and recognition as it allows for the replacement of station postinsulators and long rod insulators that are of uncertain mechanical strength.

Recently, the estimated lifespan of long rod insulators by the method of acoustic emission depended on the choice of insulators and producers during the modernisation of the Polish 220 kV and 400 kV transmission lines. Despite the strong competition of many reputable firms worldwide the tender entrusted the production to the firm ZAPEL in Boguchwala. The crucial argument was the long life-time of their insulators (reaching 50 years); the latter was evaluated by Prof. Ranachowski.

Among the achievements in the production engineering of materials of desirable parameters, i.e. among the investigations in the field of materials technology, the study and going into production of the following materials should be mentioned:

- the materials for the production of insulators working at high temperatures,
- the silicate-zirconium materials for chambers of medium-voltage contactors,
- arc-resistant materials for high-voltage arc interruption chambers [8],
- steatite materials [16, 17] for electronic and electrical engineering,
- ceramics for electro-optics [27],
- cordierite materials for welding technology,
- polimeric materials of decreased electric resistance for fuel tanks.

The accomplishment of the above tasks were possible only on condition that the measurement techniques and devices were constantly improved. This concerned the comprehensive application of methods used in materials engineering, mainly, as mentioned above, the methods of structural analysis, acoustic techniques including ultrasound velocity and attenuation measurements as well as the AE methods. The application of the acoustic emission is a particularly momentous achievement of Prof. Ranachowski. Besides the innovative application of this method to the mentioned above investigation of materials, Prof. Ranachowski receives the credit for putting the AE method into practise as a tool for the testing of technical objects. This is the consequence of the many years' standing work of Prof. Ranachowski and of the team working under his leadership. The goals of their activities were:

- initiation of the production and the perfection of analyzers of acoustic emission. The DEMA analyzers, worked out under the leadership of Prof. Ranachowski, are currently in use in many scientific and industrial laboratories;
- popularising of the AE methods amid scientists and engineers. This aim was accomplished by papers in professional journals, collective monographs and conference materials;
- promotion of the scientific staff dealing with those problems that resulted in the initiation of Ph.D. dissertations and postdoctoral lecturing qualifications as well as in the endorsement of applications for academic titles for scientists dealing with the acoustic emission.

The most important publications of prof. J. Ranachowski (in chronological order)

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