Załącznik 4

ANNEX 4

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

Krzysztof Kosała, Ph.D. Eng.

Department of Mechanics and Vibroacoustics

Faculty of Mechanical Engineering and Robotics

Stanisław Staszic AGH University of Science and Technology in Kraków

Kraków, September 2014

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1. Given name and surname

Krzysztof Kosała

2. Diplomas awarded, scientific and artistic degrees

Obtained academic title: **Master's degree in mechanical engineering**
2001, Stanisław Staszic AGH University of Science and Technology in Kraków, Faculty of Mechanical Engineering and Robotics
Discipline: Mechanical Engineering
Specialization: vibroacoustics and sound engineering
Subject of master thesis: *Methods for acoustic assessment of sacral objects*
Supervisor: Professor Zbigniew Engel Ph.D., D.Sc.,Eng., Stanisław Staszic AGH University of Science and Technology in Kraków

Obtained degree: **Ph. D.**
2004, Stanisław Staszic AGH University of Science and Technology in Kraków, Faculty of Mechanical Engineering and Robotics
Discipline: mechanics
Scientific specialization: vibroacoustics, sound engineering
Subject of dissertation thesis: *Acoustic issues in sacral objects*
Supervisor: Professor Zbigniew Engel Ph.D., D.Sc.,Eng., Stanisław Staszic AGH University of Science and Technology in Kraków

3. Information on employment in research institutions

- 2000–2001 trainee assistant (fifth year of study) at the Faculty of Mechanical Engineering and Robotics, Stanisław Staszic AGH University of Science and Technology in Kraków

- 2003–2005 assistant in the Department of Mechanics and and Vibroacoustics, Faculty of Mechanical Engineering and Robotics, Stanisław Staszic AGH University of Science and Technology in Kraków

- since 2005 assistant professor in the Department of Mechanics and and Vibroacoustics, Faculty of Mechanical Engineering and Robotics, Stanisław Staszic AGH University of Science and Technology in Kraków

4. Presentation of a scientific accomplishment, resulting from Article 16 (2) of the Act on University Degrees and the University Title and on University Degrees and the University Title in the Field of Fine Arts of March 14, 2003 (Dz. U. [Law Gazette] No 65, item 595, with later amendments)

My scientific accomplishment, obtained after receiving the doctoral degree, constituting significant contribution to the development of the scientific discipline mechanics, specified in Article 16 (2) of the Act, is monothematic series of publications:

a) title of the scientific accomplishment

"Singular Value Decomposition in investigations of vibroacoustic processes at the example of assessing and shaping acoustic properties of selected objects".

b) (author/ authors, title/ publication titles, year of publication, publisher)

[A1] K. Kosała, *Global index of the acoustic quality of sacral buildings at incomplete information*. Archives of Acoustics, 33, 2, 2008, 165–183. (*Publication indexed in data bases of the Journal Citation Reports (JCR) and Web of Science*).

[A2] K. Kosała, *Calculation models for acoustic analysis of sacral objects*. Archives of Acoustics, 34, 1, 2009, 3–11. IF= 0.313.[1]

[A3] K. Kosała, *A single number index to assess selected acoustic parameters in churches with redundant information*. Archives of Acoustic, 36, 3, 2011, 545–560. IF= 0.847, DOI: 10.2478/v10168-011-0039-3.

[A4] K. Kosała, *Singular vectors in acoustic simulation tests of st. Paul the Apostle Church in Bochnia*. Archives of Acoustic, 37, 1, 2012, 23–30. IF= 0.829, DOI: 10.2478/v10168-012-0004-9.

[A5] K. Kosała, *Synthesis of uncorrelated acoustic quality evaluation indices of buildings*. Acta Physica Polonica A, 123, 2013, 1064–1067. IF= 0.604, DOI: 10.12693/APhysPolA.123.1064.

[A6] K. Kosała (50%), Z.W. Engel, *Assessing the acoustic properties of Roman Catholic churches: A new approach*. Applied Acoustics, 74, 2013, 1144–1152. IF= 1.068, DOI: 10.1016/j.apacoust.2013.03.013.

[A7] K. Kosała, *A comparative analysis of acoustic of Roman Catholic churches by means of the index method.* Acta Physica Polonica A, 125, 2014, 99–102. IF= 0.604, DOI: 10.12693/APhysPolA.125.A-99.

[1] Impact Factor (IF) indices for papers in scientific journals obtained on the bases of the Journal Citation Reports (JCR) - given in Annex 6 - are in agreement with the year of publishing (IF from 2013 is given for paper [A7], published in 2014).

c) discussion of the scientific objective of the above works as well as result received, inclusive of a discussion of their application

The studies, analyses and assessments of vibroacoustic processes occurring in different objects such as machines, devices, factory floors or public facilities utilise more and more advanced methods based on reciprocity, inversion and, in the case of acoustic quality assessments, based on indices. Index-based assessments are extremely useful in diagnostics, i.e. the description of the current quality or fitness of a given objects for its intended purpose. The indices can simplify the presentation of diverse, often complex phenomena occurring in the area under measurement, as well as measure the changes in them. Index methods used in studies of vibroacoustic processes are used to assess these processes. Single-number indices can be used in selected cases. Such indices are general measures and functions of partial indices, that provide more detailed information concerning a phenomenon. My works discuss the aspect of index assessment of acoustic quality of a group of objects, namely Roman Catholic churches. The works on the index method for assessing such facilities were included in my earlier studies. However, the proposed method required further development and verification on a larger number of interiors. **The main scientific goal of the above works and the results obtained from them was the use of an analytical tool, i.e. the SVD (Singular Value Decomposition), to develop a mathematical formalism to be used in analyses, uniform assessment and formation of the acoustic of Roman Catholic churches, which are currently in use, being designed or undergoing acoustic adaptation**. In my work so far, I have not encountered any publications on the use of SVD in the assessment of the acoustic properties of religious objects, nor in the synthesis of indices leading to a single-number assessment index.

Below, I will present the main goals and detailed conclusions of individual works comprising a monothematic cycle of publications.

Ad. [A1]. The main goal of this work were the preliminary studies of using the singular value decomposition in analysing the acoustic properties of several already studied Roman Catholic churches. The studies and analyses shown in this work are a continuation of the author's studies on the index method for acoustic assessment of religious objects proposed [P1][*]. The decomposition (SVD) related to the so-called the index observation matrix of sacral objects ***A***, with the dimensions of 6×3, which served as an empirical model (6 studies churches, 3 mutually correlated indices describing the acoustic quality of a given interior: reverberation index W_r^*, intelligibility of speech index W_{is} and musical sound quality index W_m. The use of SVD was preceded by some modifications of the calculation procedure in the index method proposed in [P1], which was shown in the article. These modifications involved, above all, the inclusion in the global assessment of not 5 as before, but 3 partial indices listed above, as well as the introduction of a new, simplified formula for the reverberation index W_r^*. The SVD of the index observation matrix yielded the transformation of initial variables in the form of correlated indices into new, mutually orthogonal variables. Performing an SVD in the Matlab environment allowed for reducing the empirical model through appropriate

[*] Numbering of all works cited in the summary of professional accomplishments is in agreement with the list of published scientific papers (Annex 6).

approximation. By using the first singular value obtained from SVD σ_1, which is the most informative compared to the other ones (σ_1=88%, σ_2=10%, σ_3=2%), a simplified empirical model was obtained, which was used for: (i) quantitative analysis of the weight of partial indices usable in calculating the value of the global index of acoustic quality assessment in sacral objects W_{AQS}^{**},, (ii) obtaining a formula for the global index of acoustic quality of sacral objects with incomplete information concerning the building $W_{AQS}^{W_r^*}$. With measured reverberation time of an interior, we can calculate the reverberation index W_r^* and use this single piece of information to foresee the approximate global index of acoustic quality of a temple, as shown in the article. The formulae for approximate values of indices of intelligibility of speech and music sound quality depending on a single reverberation index as also useful. The most important cognitive results obtained in the work include:

- The use of Singual Value Decomposition in analysing the acoustic properties of sacral objects and the development, based on singular values obtained using SVD, of new formulae for single-number global assessments (W_{AQS}^{**} i $W_{AQS}^{W_r^*}$).
- The comparison of acoustic properties of 10 Roman Catholic churches using single-number indices. The assessment of four of them was done with incomplete information, using an index developed for this purpose $W_{AQS}^{W_r^*}$. Due to the limited equipment available at the time at the Department of Mechanics and Vibroacoustics, the only parameter determined in studies of several churches, performed for MA theses, was the basic acoustic parameter of reverberation time.
- Obtaining a larger spread of calculated values of the global index of acoustic quality of sacral objects W_{AQS}^{**}, of 0.2 to 0.8. Before, the index assessment of acoustic quality gave us the results of global single-number assessments W_{AQS} within the range of 0.5 to 0.7.
- The confirmation of the compatibility between the subjective opinions of users of religious buildings concerning bad acoustic parameters of modern churches built on elliptical and circular plans with the low values of global index of acoustic quality of religious buildings close to 0 ($W_{AQS}^{W_r^*}$=0.2), which means bad acoustic properties according to the index method.

Ad. [A2]. The article presents the results of studies that continue the analysis of acoustic properties of sacral objects using the singular value decomposition technique. The results of these studies were discussed in conference [K19]. The goal of these studies was to apply the SVD to the observation matrix with larger dimensions than before (6x5). The analysis involved 5 partial indices developed as part of earlier research into index method: four developed in article [P1], i.e.: music sound quality, intelligibility of speech, external disturbances and uniformity of loudness indices, and one developed in [**A1**], i.e. the modified reverberation index. The SVD technique was used to study the percentage proportion of explanation of information concerning independent indices by consecutive singular components, as well as to perform quantitative analyses of weights of partial indices used in the formula for the global single-number index of acoustic quality of sacral objects. A comparison was done between the global assessments obtained using a 3-index calculation model (described in [**A1**]), and a 5-index model. The most important cognitive results obtained in the work include:

- The development of a 5-index calculation model for acoustic analyses of temples, which provides further information concerning the independent indices in the observation matrix. The percentage share of explanation of information by consecutive singular component are, respectively: 65, 20, 10, 4 and 1% of the total information, which means, that a 3rd order approximation which uses singular components σ_1, σ_2 and σ_3 allows for reducing the calculation model with the Frobenius error close to 0. The last two components have very low values compared to the other ones and are lower than 10%, considered to be the value of informational noise. The sum of the rest of the components gives the result of 95% of explanation of the phenomenon.
- The finding, based on research, that the approximation of the first rank for a 5-index model for quantitative analysis of weights of individual partial indices (this was shown for a 3-index model in [**A1**]) yields non-satisfactory results. Analyses have shown, that this method of obtaining weight is useful, when the indices in the observation matrix are correlated, which is the case in the simplified 3-index model (reverberation, music sound quality and intelligibility of speech). The percentage share of the first singular component σ_1 was large (88%) in the simplified model, as compared with the other components. On the other hand, in the 5-index model, the share of component σ_1 of 65%, as applied to index weight calculations using the approximation of the first rank, was insufficient to approximate the structure of interrelations in an index observation matrix. The error of the approximation of the first rank in the two calculation models differs by approximately an order of magnitude.

Ad. [A3] This article proposed a different approach in the index assessment of acoustic properties of church interiors. The determination of weights of chosen, strongly correlated partial indices, which was the main aim of the research described in the article, involved the solution to the problem of redundant information, i.e. a system of overdetermined linear equations using a calculated pseudoinverse observation matrix. Analyses were done on a 6x3 index observation matrix of sacral objects containing new partial indices. The most important cognitive results obtained in the work include:

- The development of new calculation procedures for three partial indices: reverberation W_R, music sound W_M, and speech intelligibility W_S. Using simplifications in calculating the values of partial indices resulted in stronger linear correlation between partial indices. The linear correlation coefficients are within the range of 0.92-0.98. The decision to not include the audience in the building in the formula for reverberation index W_R gave the benefits of: (i) simplified calculations, (ii) lower risk of certain errors when making calculations that involve the audience and (iii) a larger result spread as compared to previous index (shown in [**A1**]). Using the new reverberation index W_R for 6 Roman Catholic churches, the spread is from 0 (bad reverberation conditions, meaning that the determined average in octave bands of frequency reverberation time diverges from the recommended reverberation time by 4.5 s) to

1 (very good reverberation conditions that correspond to the values preferred for churches of this denomination).

- The development of new formulae for global indices of chosen acoustic parameters in religious buildings: W'_{SAP} and W_{SAP}. The first index allows for determining the global indices of buildings subjected to SVD, serving as components of index observation matrix ***A***. A single-number index W'_{SAP} is a function of the left and right singular vectors ***A'*** obtained from the SVD of matrix ***A*** , calculated using the approximation of the first rank of matrix ***A***. The second global index W_{SAP} is a universal index. This means, that treating the 6x3 index observation matrix ***A*** as a standard allows us to use the formula for W_{SAP} to calculate single-number index for any Roman Catholic church (not included in the observation matrix ***A***). The index W_{SAP}, which is a weighted sum of partial indices W_R, W_M and W_S, was developed by solving a system of 6 linear equations with 3 unknowns, i.e. the weights. An overdetermined system of equations with a number of equations bigger than the number of unknowns describes the problem of redundant information. The resolution of the problem of redundant information means the solution of a set of equations in the form of $\boldsymbol{Ax}=\boldsymbol{b}$, where ***x*** is the searched vector of solutions (vector of weights), and ***b*** is the vector of the right side of the equation (the vector of global indices W'_{SAP}). Knowing the SVD of matrices ***A***, we can determine the solution of the problem, i.e. the linear problem of least squares. Based on matrix $\boldsymbol{A}^+$ (pseudoinverse to ***A***) and vector ***b***, we determine vector $\boldsymbol{x}^*=\boldsymbol{A}^+\boldsymbol{b}$. The comparison of global indices of 6 Roman Catholic churches W'_{SAP} and W_{SAP} shows, that the values are practically identical. The very small differences in the resulting values are within the range of 0.02-0.03.
- Obtaining the highest ever spread of global index through index analysis of chosen acoustic parameters of sacral objects using a single-number global index, which is a function of 3 correlated partial indices, performed for 6 Roman Catholic churches. A historic wooden church praised for its acoustic properties obtained a maximum value of the global index W_{SAP}=1, which means, according to the index method, very good acoustic properties, while a building with negative opinions among its users, i.e. a modern church built on an ellipse, obtained a W_{SAP}=0.2, that is close to 0, which means bad acoustic properties that make it acoustically unfit for its function.

Ad. [A4]. The goal of this study was to develop a global index for assessing acoustic quality of a religious building in simulations of acoustic adaptation of a church. A single-number global index of assessment of simulation variant W_{GS} is based on four partial indices: reverberation, speech intelligibility, music sound and the new index proposed in the article - sound strength. The numerical index of acoustic quality described the approximate degree of divergence of acoustic parameters from the recommended values. More detailed information are described by partial indices. The study was performed in the interior of the St. Paul the Apostle church in Bochnia, which is not praised by the users for its acoustics, which is proven by acoustic parameter analyses performed as part of earlier research. The most important cognitive results obtained in the work include:

- The development of a geometric model (in AutoCad) consisting of 522 surfaces and an acoustic model of the interior of the church (in CATT-Acoustic). The acoustic model was calibrated using reverberation time in the function of frequency measured in the real building.
- Obtaining the values of parameters for the interior through simulation, especially: reverberation time RT, music clarity index C_{80}, rapid speech intelligibility index RASTI, sound strength G, (with their characteristic frequencies) for 17 simulation variants, taking into consideration, among others, the presence of an audience and proposed various sound-absorbing materials.
- The development of the ***IOMSV*** *(Index Observation Matrix of Simulation Variants),* with dimensions of 17 × 4, based on determined partial indices of assessment: reverberation, speech intelligibility and music sound quality according to calculation procedures shown in [**A3**] and the new index of sound strength.
- Singular value decomposition of ***IOMSV*** and learning the share of explanation of information concerning independent variables using consecutive singular components $\sigma_1 \div \sigma_4$, respectively 88, 7, 5 and 1%, as well as the development of Perfectly correlated Index Observation Matrix (***PIOM***). The ***PIOM*** was obtained using the approximation of the first rank utilising the first singular value (the largest of all obtained values), as well as the first left and right singular vectors. Vector $\boldsymbol{a_1'}$ contains the values of global indices W_{GS}' of individual variants of simulation and corresponds to the input reverberation index, which is the most strongly correlated with other partial indices. The linear correlation coefficient between the reverberation index and vector $\boldsymbol{a_1'}$ is 0.99, and between ***IOMSV*** and ***PIOM***: 0.96.
- The development of a universal formula for simulation variant assessment - global index W_{GS}. Having determined, based on simulation results, the values of 4 acoustic parameters averaged in octave bands: reverberation time RT, music clarity index C_{80}, rapid speech intelligibility index RASTI and sound strength G, we can assess any simulation variant of acoustic parameters after the partial indices are calculated. In order to determine the weights of four partial indices, in the formula for W_{GS}, we used the method for solving the problem of redundant information described in [**A3**], where the weights were calculated for 3 partial indices. The universal formula for the global index W_{GS} is easy to use and does not require the designer or assessor to know the SVD technique.
- The determination of the most advantageous simulation variant (no. 7) of acoustic adaptation, i.e. K13 spray-on cellulose plaster, taking into consideration the amount and distribution of this material, which should, according to simulation results, ensure the reverberation time and its flat curve in the function of frequency recommended for this building.
- The study of the range of values of the global index from 0.2 - the worst acoustic parameters hugely divergent from recommended values (variant no. 1 without adaptation) to 0.9 - the best acoustic parameters as recommended (variants no. 7 and 10).
- The determination that the inclusion of audience only, without acoustic adaptation (variant no. 2), does not improve the acoustic parameters significantly, with forecast W_{GS}=0.5, similar to using variants 13 and 15 with a small amount of sound-absorbing material with W_{GS}=0.4-0.5.

- Using the single-number index W_{GS} to prove that variant 7 is one of the best acoustic adaptation solutions in terms of acoustics, forecasting proper reverberation conditions for liturgy while ensuring good speech transmission and high-quality sound of music. The other good simulation variant (no. 10), with W_{GS}=0.9, does not include the audience and requires a larger amount of absorbing material.

Ad. [A5] The main goal of the research presented in the paper was to check whether the construction of single-number indices of acoustic quality assessment using SVD may yield good results when the index matrix of observation undergoing SVD includes not only correlated partial indices, but also uncorrelated indices. The paper presents 2 methods of synthesising partial indices to obtain single-number global indices W_{Gs} and W_{Gd}, using an example assessment of a group of public buildings - 6 Roman Catholic churches.

The first method involved a synthesis of two uncorrelated indices, which gave the global index W_{Gs} as a weighted sum of the following indices: (i) single-number, the so-called local index W_l, i.e. the index of chosen correlated acoustic parameters, obtained using SVD, described in [**A3**] and (ii) the uncorrelated external disturbances index W_{ZZ}. Three mutually correlated partial indices: reverberation W_P, music sound W_M and speech intelligibility W_Z were calculated using current procedures described in [**A3**]. A synthesis of 2 uncorrelated indices W_l and W_{ZZ} was done using adapted statistic method used in econometrics, i.e. the <u>C</u>omparative <u>M</u>ultivariate <u>A</u>nalysis (CMA). Property variability coefficients were used to calculate the measures of relative informative value, which consist of the weights of ω_j variables of indices W_l and W_{ZZ}.

The second method of obtaining the single-number global index of assessment W_{Gd} was an attempt to use the new approach to using SVD in constructing a synthetic single-number index from any (correlated and uncorrelated) indices within a 6×4 matrix of observations. The partial indices are W_P, W_M, W_Z and W_{ZZ}. In order to do this, SVD was used to transform the variables included in the index matrix of observations into a new set of components that are not correlated with one another. The global index W_{Gd} obtained from the decomposition of this matrix is for the *i*-th building a weighted sum of singular vectors obtained from SVD: $\boldsymbol{u}_i$ and $\boldsymbol{v}_i$. The shares of information concerning independent features obtained from singular values σ_i, describing the variability of properties, were proposed as weights of those properties. The resulting values of single-number assessments were compared. The most important cognitive results obtained in the work include:

- The conclusion that an index description of acoustic properties of buildings may be done in a thorough way using one number. The global single-number index, serving as a general measure of the assessment, is a function of several partial indices providing more detailed information concerning a phenomenon. The approximate global assessment is related to the acoustic functions and intended purpose of a given building with a given range of acoustic production. The single-number assessment is preceded by a series of experimental tests of acoustic parameters performed in a real building.
- The conclusion, that the construction of a synthetic single-number index of uncorrelated partial indices of assessment may be done using the following methods: statistical - CMA and SVD,

which was verified on a selected groups of Roman Catholic churches. Due to their distinguishing characteristics, these building have to combine the compromise requirements of good conditions for music and speech transmission.

- Proving that the values of single-number global indices obtained using to different methods are close and yield similar effects when assessing acoustic quality. Due to the fact that the global index W_{Gd} obtained through SVD decomposition is more strongly correlated with the initial partial indices (averaged linear correlation coefficient r=0.9186) than index W_{Gs} obtained using statistical method (r=0.9082), the assessment performed using W_{Gd} seems more reliable.
- Acoustic property analyses of 6 Roman Catholic churches using indices and the confirmation of compatibility of these assessments with previous studies. Single-number assessment of acoustic quality performed using W_{Gd} with partial indices W_P, W_M, W_Z and W_{ZZ} has shown that the best acoustic parameters regarding reverberation, speech intelligibility, music sound and the lack of external disturbances can be found in the historic wooden church of Saint Sebastian. The worst acoustic parameters, except for the level of external disturbances, can be found in a modern elliptical church of Saint Paul. The global index W_{Gd} based on 4 partial indices for the latter church is 0.4. Assessments done using single-number global indices have shown that the other church with bad acoustic parameters, significantly diverging form the preferred values, is the Jesuit church. Excessive reverberation of the interior results in poor speech intelligibility and low quality of music. Three churches: Holiest Sacred Heart, Reformati and Saint Clemens have global indices above 0.6, which means that their conditions are acoustically quite good for their function.

Ad. [A6]. The paper presents the results of studies and analyses of acoustic properties in Polish Roman Catholic churches using classic methods and the latest index method. The work continues the research into perfecting the index method of assessment of acoustic quality of Roman Catholic churches. The single-number assessment using global index GAP is the result of using SVD and CMA techniques, as well as mathematical operations on an 8x4 matrix of observations. Verification of the approximate method of assessment of acoustic qualities was performed in 8 Roman Catholic churches studied by the authors. These are buildings with different cubic capacities, floor shape and interior equipment. The most important cognitive results obtained in the work include:

- A cumulative comparison of analyses of acoustic parameters of 8 Roman Catholic churches. Studies have shown that good acoustic parameters can be found in smaller buildings (up to 6400 m^3), especially historic wooden buildings. Acoustic parameters are getting worse the bigger the cubic capacity. An analysis of acoustic parameters in churches allowed for concluding that the reverberation time values for the frequency of 500 Hz are within the range of 1.5 to 9.7 s. Except for one church, the remaining buildings exceed the preferred values. With the exception of historic wooden church, all churches have appropriate conditions for listening to symphonic music. None of the churches had the value of the music clarity index C_{80} averaged from 0.5, 1 and 2 kHz octave bands appropriate for organ music. All churches had poor speech intelligibility. The rapid speech transmission index RASTI was within 0.4÷0.2, with the exception of the wooden church, whose index is acceptable to good, which means poor or bad speech intelligibility. The determined spectra of acoustic background for all churches were lower than acceptable values defined by N35 curve, which provides good conditions for liturgy.

- Proving large similarities between the results of analyses and assessments of acoustic properties of 8 Roman Catholic churches using classic methods (acoustic parameters) and the proposed index method.
- The development of a universal, easy-to-use formula for the synthetic global index, i.e. an approximate general measure that can serve for approximate comparisons of acoustic properties between Roman Catholic churches. The formula was developed mainly for non-specialists in acoustics who want to objectively and reliably learn the acoustic qualities of a given church. Such people include priests and the participants of services. An averaged, in terms of frequency and space, single-number index seems to be a helpful and comfortable tool for the researchers, especially considering its ease of use. More detailed information concerning acoustic properties are provided by partial indices, the components of the global index of assessment based on universally accepted acoustic parameters and the recommended values thereof. The analysis of partial indices may show whether a given church has an interior closer to a concert hall or a lecture hall where spoken word dominates. Partial indices are an indication which acoustic parameter requires correction. The global assessment shown in the paper is based on 4 parameters used to calculate the following indices: reverberation R, music sound M, speech intelligibility S and external disturbance D. By treating the index matrix of observation (8x4) as a standard, the resulting formula for a single-number index of acoustic properties of Roman Catholic churches and the tests of interiors' acoustic parameters, we can assess any church from outside the matrix of observations. The proposed weighted global index may be used easily in simulations and forecasting of variations in acoustic quality of churches under new construction and material solutions when performing acoustic adaptations, or the inclusion of the variable audience.
- The highest spread of global index GAP yet, which a function of 4 partial indices: from 0.2 (bad acoustic properties, as in Saint Paul's church) to 1 (very good acoustic properties, as in the historic wooden church), applied to the largest number of buildings: 8 churches.
- Showing a new attempt at using SVD of matrix of observation to obtain a single-number index RMS, which yields the best results yet. The SVD technique was used in this paper to reduce the number of correlated indices. In order to do this, one of the products of the decomposition of the matrix of observation, matrix $\boldsymbol{V}$, was used for linear transformation of standardised data by the product of matrices $\boldsymbol{A}$ and $\boldsymbol{V}$. By using the first, most significant vector $\boldsymbol{b_1}$ normalised to the range of <0.1> in the resulting 8x3 matrix $\boldsymbol{B}$, which contains 3 uncorrelated column vectors $\boldsymbol{b_i}$, we obtain the vector of single-number indices RMS. The RMS index is very strongly correlated with partial indices R, M and S, but it is not correlated with index D. The studies of linear correlation coefficient have shown respectively the values of 0.97; 0.98; 0.97 and 0.08.

The values of single-number indices RMS obtained using SVD technique, along with indices D for the churches studied, were used in calculating the weights for the global index GAP using CMA method.

Ad. [A7] The goal of the next stage of studies on perfecting the index method for assessing the acoustic quality of Roman Catholic churches was the development of a new formula for the global single-number index expanded by another uncorrelated partial index using a larger-than-before number of studied buildings. The calculation procedure for the proposed global index GI was based, among others, on the results obtained from the SVD of a 12x3 matrix of observations containing correlated partial indices: reverberation R, music sound M and speech intelligibility S. The resulting single-number index of chosen acoustic parameters RMS, along with uncorrelated indices of external disturbance D and sound strength S_T are the components in the weighted sum defining the global index GI. The weights of uncorrelated indices were calculated using comparative multi-dimensional analysis (CMA). The most important cognitive results obtained in the work include:

- The development of a new approach using SVD technique to obtain a single-number index RMS, reduced from three correlated other partial indices R, M and S using linear transformation performed on a bigger, 12-object matrix of observation. The linear correlation coefficients between the reduced index RMS and three partial indices R, M and S are, respectively, 0.982, 0.981 and 0.979. An analysis of linear correlation between the three partial indices R, M and S has shown that the correlation is very strong. The linear correlation coefficients are equal to: R<->M: 0.947; R<->S: 0.941; M<->S: 0.938. The vector containing RMS for 12 churches was determined as described in [**A6**]. The shares of explanation of information by individual components obtained through the SVD of 12×3 matrix of observations are: 78, 12 and 10%. It was assumed, that vectors $\boldsymbol{b}_2$ and $\boldsymbol{b}_3$, serving as column vectors in matrix $\boldsymbol{B}=\boldsymbol{A}\boldsymbol{V}=\boldsymbol{U}\boldsymbol{\Sigma}$, can be rejected, thus reducing the number of indices to one vector $\boldsymbol{b}_1$, which was then normalised to the range of <0.1> and served as the vector for reduced indices RMS.
- The conclusion that the index description of the acoustic properties of Roman Catholic churches may be done using a single-number method, even considering the fifth partial index related to sound strength and the development of a universal formula for global index GI. The values of weights of uncorrelated indices obtained using CMA based on the results of studies of 12 churches, are proposed as an assessment for any Roman Catholic church with a cubic capacity of 1100 to 41000 m^3. The assessment of any church has to be preceded by the study of acoustic parameters of the interior, such as: reverberation time RT, music clarity index C_{80}, rapid speech transmission index RASTI, external disturbance level L_A and sound strength G. Then, partial indices R, M, S, D and S_T are calculated. Three partial indices R, M and S have to be inserted as the next row in the index matrix of observations shown in the paper. Then the new index RMS has to be calculated using the procedure shown and the SVD technique. After the RMS is determined and the values of the two remaining partial indices D and S_T are calculated, the global index GI can be calculated for a given church.

- Obtaining an index comparative analysis of acoustic properties of 12 Roman Catholic churches in the form of partial assessment and approximate global assessment, where partial indices and the global index assume the value from 0 for buildings with bad acoustic properties to 1 for objects with very good acoustic properties corresponding to preferred values. The global index GI assumes the values from the widest range yet of 0.1 to 1. The comparative analysis of 12 churches using the global index GI has shown that only one church, Saint Sebastian (GI=1) has very good acoustic quality. Two historic wooden churches with the GI=0.8 are close to that grade. The worst acoustic properties, i.e. the lowest GI index, are found in Saint Peter and Paul (GI=0.2) and the Sanctuary of Divine Mercy (GI=0.2). An analysis using partial indices has shown that 3 historic wooden churches have very good reverberation conditions (R=1), which means good speech intelligibility (S≈0.5) and good sound of music (M=1). The worst acoustic parameters are exhibited by churches with large cubic capacities. Their reverberation indices are close or equal to 0. The speech intelligibility of these churches is bad (S<0.3). Only 5 among the 12 buildings have the conditions that work in favour of uninterrupted prayer or meditation (D=1). Two churches, namely the Sanctuary of Divine Mercy and the Saint Peter and Paul have the sound strength indices S_T=0.

Summary

These articles that comprise a monothematic cycle show the experimental determination of acoustic parameters of 12 public buildings (8 buildings were studies once the doctoral thesis was completed), namely Roman Catholic churches. Based on these parameters, thorough assessment of acoustic properties of these buildings was conducted to determine the current state and their acoustic fitness for their function. The unified assessment of acoustic quality is possible using the developed formula for the single-number global index of acoustic quality of Roman Catholic churches, which is an approximate general measure of assessment and a function of 5 partial indices. The global index was developed using singular value decomposition on the so-called the index observations matrix of the buildings. The singular values and vectors obtained through SVD were the basis for the development of mathematical formalism in the form of a formula for a single-number index.

According to the author, the most important original scientific and research accomplishments of the cycle of publications, significantly contributing to mechanics, are:

- Using the example of Roman Catholic churches to show that the assessment of acoustic properties of a building can be performed in a unified manner using one number. Index methods can be used in studying vibroacoustic processes, while single-number indices can be used or the assessment of these processes in selected cases. Additionally, the goal and the target audience of these assessment indices have to be specified. A single-number index may be used by the general public and, in some cases, by the politicians. But these indices can in many cases be insufficient for scientific purposes.
- Showing the usefulness of the Singular Value Decomposition as an analytical tool in building single-number indices, as well as in the analysis and assessment of acoustic quality of chosen buildings, as proven by Roman Catholic churches. The SVD technique may be used to: (i)

reduce intercorrelated partial indices into a single-number index, using singular components, singular vectors and linear transformation obtained from the decomposition, as well as to (ii) perform syntheses of uncorrelated indices with independent properties obtained from singular values describing the variability of properties, with a proposition to use them as the weights of these properties. The comparative multi-dimensional analysis method (CMA), which can also be used in synthesising independent features (indices), is an auxiliary tool in building single-number (global) indices.

- Showing the usefulness of SVD to solve the problems of assessing acoustic quality of buildings with incomplete information, as well as the problems of selecting the weights of partial indices with redundant information, where an overdetermined set of linear equations occurs.
- Determining the degree of correlation between the single-number global assessments of acoustic quality of selected buildings (Roman Catholic churches) and the initial symptoms obtained in acoustic studies, i.e. between the acoustic parameters and the determined partial indices.
- The implementation of the index method for the assessment of acoustic properties of 12 real-life churches and for the analyses of acoustic adaptation of one church. Simulations, using an additional tool of proposed indices, allow for assessing and forming the acoustic properties of the interior according to the expectations of the administrators of the buildings, the designers, the users and the budgetary considerations of the adaptation.

Additionally, the results of the research can be used in:

- developing the design guidelines concerning the acoustic quality of Roman Catholic churches,
- developing (or modifying) the index methods of assessing the acoustic quality of other types of objects, such as machines, devices, public facilities (including classrooms), industrial facilities such as factory halls, opencast mines of rock materials, etc.
- acoustic adaptations of Roman Catholic churches with faulty acoustics or in designing new buildings using simulations based on the acoustic model of a church,
- developing vibroacoustic indices of sustainable development used to monitor and update development strategies.

5. Other scientific and research accomplishments

5.1. Accomplishments prior to gaining the title of Doctor of Technical Sciences

My scientific work started while I was a student at the AGH University of Science and Technology in Cracow, at the Faculty of Mechanical Engineering and Robotics, beginning in 1996. As a senior, I became a trainee assistant and started teaching classes in Mechanics. While working as the associate, I became involved in the scientific and research work at the Department of Mechanics and Vibroacoustics. I participated in research projects [G1,G2][*] concerning the issue of impact noise in

[*] Numbering of all works cited in the summary of professional accomplishments is in agreement with the list of published scientific papers (Annex 6).

industry and its control in presses and [G3] concerning highly effective and modern methods for limiting vibroacoustic energy in industrial settings, developing technical documentation of noise protection for mechanical presses.

I defended my master's thesis entitled "Methods for acoustic assessment of sacral objects", advised by Prof. Zbigniew Engel, Ph.D., D.Sc.,Eng., in 2001. The goal of this thesis was to analyse the current methods of acoustic assessment of sacral objects treated as auditoriums for listening to speech and music. After defending my thesis in 2001, I started my doctoral studies at the Faculty of Mechanical Engineering and Robotics at AGH. While continuing my studies on the acoustics of religious interiors [K1], [P6], I also progressed with my research on industrial noise. The subjects of my studies and analyses included: presses, with the results of groups research on one of the noise protection devices, i.e. moving sound-insulation, implemented in a real press in the laboratory of the Department of Mechanics and Vibroacoustic of AGH, were presented by me at a conference [K10] and published as a co-author in the Work Safety periodical [P5]; transformers, by co-authoring a publication [P4], and the issues of modelling the acoustic field in industrial halls [K12].

In October 2003, I began working as a teaching assistant at the Faculty of Mechanical Engineering and Vibroacoustic of the AGH. As a teaching assistant, I taught classes in Mechanics and Introduction to computer science for full-time students of the IMiR AGH. My interest in the acoustics of sacral interiors resulted in further development of the topic in my doctoral thesis. I participated in acoustic studies as part of master's theses under the advisory of Prof. Engel, as well as my own works in determining the acoustic parameters of several Roman Catholic churches. In 2003-2004, I received a supervisory grant under the advisory of Prof. Engel in the "Acoustic issues in sacral objects" [G4], which resulted in my doctoral thesis, scientific publications and papers presented in conferences. The aim of my thesis was to use the classically studied acoustic properties of sacral objects to develop a unified method of acoustic assessment of temple interiors. In my thesis, I classified religious buildings, I review classic methods adapted for acoustic assessment of sacral objects and analysed these methods, I studied the acoustic parameters of selected churches and their influence on shaping the acoustic quality of religious interiors, I developed an index method for assessing sacral objects based on a single-number global assessment index as a function of 5 partial indices. I verified this proposed method on 4 selected Roman Catholic churches. The results of my studies and analyses were presented in an international conference on Sacral and Monumental Buildings [K2], as well as 3 national conferences of the Open Seminar in Acoustic OSA [K11, K13, K14], as well as in 2 publications in periodicals listed by the Ministry of Science and Higher Education [P7, P8]. The public defense of my doctoral thesis entitled "Acoustic issues in sacral objects" took place on October 28, 2004. Soon after, I received the title of Doctor of Technical Sciences in Mechanics. Information concerning my publications before my doctoral thesis are included in chapter 6 of my summary of professional accomplishments (in the table listing my accomplishments) and in annex 6 (list of publications [P4-P8], [K1, K2], [K10-K14], and research projects [G1-G4]).

5.2. Other accomplishments after gaining the title of Doctor of Technical Sciences

In March 2005, I was hired as an assistant professor at the Department of Mechanics and Vibroacoustics at the Faculty of Mechanical Engineering and Robotics of AGH. While working at this position, my other scientific and research interest not directly concerning my main scientific accomplishments, involved the following:

1. Acoustics problems in sacral objects.
2. Studies and analyses of vibroacoustic process in technical systems and objects.
3. Studies, assessments and formation of acoustic environment in opencast mines of rock minerals.

Ad. 1.

In many countries, the formation of acoustic conditions of religious interior has been discussed in scientific studies, and the temple design process has usually been preceded by detailed analyses aimed at assessing the acoustic qualities of the newly designed interior. Such analyses involve recommendations for designers concerning possible acoustic adaptations of the interiors in order to achieve a proper acoustic environment. Based on the studies of Polish churches, mainly as part of master's theses, we can conclude that the formation of their acoustic properties was not appropriately considered when designing, constructing and modernising them. The problem is especially visible in sacral objects built in contemporary Poland. Leaving the acoustics of an interior to sound engineers, who are tasked with improving the sound of music or speech transmission when installing sound systems, is not always effective and may even lead to properties that do not meet the expectations of the congregation (the users) or o faults that limit the functionality of the temple. Such faults are often found in sacral objects constructed on a circle, ellipse or spiral. The lack of methods allowing the determination of acoustic conditions in sacral objects is a real problem for designers of such buildings. Acoustic assessment of such buildings still involves methods normally used to assess concert halls, theatres and lecture halls.

The acoustic requirements of sacral objects may be divided into two general groups: the first involving liturgy and services, and the second involving cultural activities in the interiors, not always directly involving religion practised in a given church. The first group of desirable properties include: good speech transmission for the priest, good music listening conditions (including organ music in buildings with organs), singing and choir sound, and the conditions for uninterrupted prayer. The second group includes: requirements for listening to spoken word and music: low level of external disturbances, good intelligibility of spoken word, uniformity of loudness and sound quality. An acoustically well-designed religious building should meet all requirements for auditoriums, as well as the requirements for the liturgical functions of a given denomination. Unfortunately, these acoustic requirements are often contradictory when applied to religious interiors. It is really hard to design an interior that is good for listening to music, providing appropriately long reverberation time, while ensuring good speech transmission, which requires short reverberation time. Thus, acoustic design in sacral objects involves harmonious resolutions of many issues influencing the quality of the building, as well as its interiors, in agreement with the highest factor considered by the architect, i.e. the sacrum.

The briefly presented problems persuaded the researchers to develop a monograph [M1], which includes the basics of acoustics in religious buildings. Apart from basic acoustics, the monograph presents an acoustic classification of sacral objects and the descriptions of classic methods of assessing temple acoustics. It described a method of measuring acoustic parameters in religious buildings. Examples of acoustic assessments of numerous Polish and foreign sacral objects are given. The authors also propose the index method for assessing acoustic quality. The monograph also includes chapters concerning acoustic materials and systems, as well as recommendations for designers. It is complemented by the issues of correcting the acoustic environment in existing temples, the issues of sound systems in sacral objects and the basic considerations concerning bells. The monograph [M1] is meant for everyone involved in designing and operating religious buildings. It can be used by priests, designers and students interested in interior acoustics.

The selected problems of acoustics of sacral interiors considered in my doctoral thesis were by me further developed and the obtained results presented during 4 international scientific conferences [K3, K4, K5, K8] and published in conference proceedings and scientific journals [P1, P10, P11, P12].

The calculation procedure of the developed index method of acoustic assessments of sacral objects such as Roman-Catholic and Protestant churches and synagogues is presented in paper [P1]. The proposed index method was developed on the bases of analyses of classic methods applied for assessments of concert halls, opera houses and auditoriums quality. The single-number, global index of acoustic quality of sacral objects W_{AQS} is an approximate general assessment measure, while more accurate information on the most essential - for this type of interiors - acoustic parameters, in relation to their preferred values, are supplied by partial indices. Five partial indices were developed: the reverberation index: W_r, speech intelligibility index: W_{is}, external disturbances index: W_{ed}, uniformity of loudness index: W_{ul}, and music sound quality index: W_m. The worked out nomograms and equations needed for the determination of the values of the acoustic quality indices and the assumptions of the proposed index method, are given in the paper. The method verification was performed by the acoustic quality assessment of 4 Roman-Catholic churches, preceded by acoustic parameters measurements obtained from the impulse responses of interiors.

The results presented in the paper [P1] were applied by António P.O. Carvalho and Pedro M.A. Silva[2] for the acoustic quality assessment - by means of the index method - of the Holy Trinity church in the Fatima Sanctuary. This modern object, one of the largest Christian church (cubic capacity: 130 000 m^3, seating places: 9000) belongs to a few churches having interiors of very good acoustic properties, in respect of a verbal and musical acoustic production. The assessment of the very good acoustic quality obtained by the index method confirmed the good opinion of the object and the acoustic parameters values assumed by the church designers.

The results of testing Polish Roman-Catholic churches by classic methods (according to Beranek, Ando and impulse method) are given in the study [P10]. The investigations of acoustic properties of sacral objects performed by various methods (the classic adapted to sacral objects and

[2] A.P.O. Carvalho, P.M.A. Silva, *Sound, Noise and Speech at the 9000-Seat Holy Trinity Church in Fatima, Portugal.* Archives of Acoustics, 35, 2, 2010, 145-156.

index method) together with comparing the obtained results, are presented in papers [K3, K4, P11]. These investigations indicated that the best acoustic conditions favouring a wide range of acoustic productions, which take place in Roman-Catholic churches has - out of the tested objects - the historic, wooden St. Sebastian church in Strzelce Wielkie. The worst acoustic conditions were found in modern objects built on elliptical plans – St. Paul Apostle church in Bochnia and on spiral plans – St. Jan Kanty church in Krakow. It should be emphasised that assessments performed by individual classic methods are often incomplete and have to be supplemented. They do not take hold satisfactorily of the specificity of sacral interiors. However, the index method allows to determine explicitly the acoustic properties of sacral objects.

Unsatisfactory acoustic quality of the Roman-Catholic St. Paul Apostle church in Bochnia, persuaded the researchers to undertake an attempt of forecasting acoustic parameters after performing an eventual acoustic adaptation. Several simulation investigations were performed on the developed acoustic model of the tested church. The obtained results were discussed at the Conference [K8] and presented in paper [P12]. The acoustic investigations performed in this church indicated that its interior is characterised by an excessive reverberation. The measured, averaged reverberation value (T_{30}=8s) exceeds several times the preferred value (T_{30pref}=2s), which causes a weak intelligibility of speech and unsatisfactory quality of sound of music. On the bases of the performed acoustic measurements and multivariant computer simulations the acoustic adaptation which can solve this problem, simultaneously retaining the architectural form of the object, was proposed. Calculations of the computer simulation indicated that the presence of an audience only slightly improves acoustic parameters. Positive results were obtained with the acoustic adaptation in a form of sprayed cellulose plasters, which should be covering the determined surfaces of back walls and the steplike ceiling of the object. The obtained characteristic of the reverberation time as a frequency function was in agreement with the literature recommendations. Parameters concerning the intelligibility of speech ($RASTI_{before}$ =0.23; $RASTI_{after}$=0.51) and sound of music quality ($C_{80\text{-}before}$=-6dB, $C_{80\text{-}after}$=1.02 dB) were significantly improved. This solution will have the positive effect on the sound amplification system which does not fulfill its function in an object without the acoustic adaptation. These investigations can be utilised for practical aims, such as improvements of the object acoustic quality.

Researchers prognose that further investigations concerning acoustic properties of sacral objects will apply the inversion method and - the most commonly distributed in the numerical linear algebra - the Singular Value Decomposition. This Singular Value Decomposition constitutes the subject of the scientific accomplishment presented hereby for the assessment.

The possibility of the application of the inversion method in the acoustic analysis of sacral objects discussed in [K5], is based on the determination of individual partial indices at the known (or assumed) value of the global index of the acoustic quality of the sacral object. Simulation investigations carried out on the acoustic model of the object can be used for solving this problem. Parameters of the model such as: interior geometry, finishing materials, placements of receivers and sound sources, dimension of absorbing surfaces corresponding to the audience presence, can be changed without any costs. As the result of the performed simulations the acoustic parameters of the tested object are obtained and on their bases the values of partial indices and of the global index calculated. These types of investigations can be utilised in future at designing new sacral objects or at acoustic adaptation of churches of a poor acoustic quality.

Ad. 2.

All vibration and acoustic effects occurring in the nature, technique, machines and devices are understood as vibroacoustic processes. Thus, they occur in the natural environment as well as in the life and leisure environment of humans. With the notion of vibroacoustic processes is related the vibroacoustics, that is the science field dealing with all vibration and acoustic problems occurring in the nature, technique, machines, devices, means of transportation, thus in the broadly understood environment. Vibroacoustics deals with vibroacoustic processes, that is to say with all vibrational and acoustical waveforms related causally to each other. Vibroacoustic problems can be approached from various points of view. From the one side vibroacoustic processes are harmful, have a negative influence of human and other living creatures organisms, cause disturbances in proper operations of machines and devices decreasing their durability and reliability, have negative influences on structures and buildings (vibrations and noises). The task of designers and building engineers is to limit or eliminate sources of vibroacoustic energy. However, from the other side the vibroacoustic processes are useful factors intentionally introduced for the realisation of the determined technological process. As examples can serve vibratory machines and devices such as transporting devices, vibratory screens or ultrasound shot-blasting machines. Also the proper sound amplification systems are being introduced - on purpose - into concert halls, churches etc.

Investigations being carried out in scientific centres of the whole world are related to more and more modern methods of analysing vibration and acoustic processes. For investigating and assessing of vibroacoustic processes occurring in machines, devices, factory buildings and other objects, the reciprocity and inversion methods are applied, while for the acoustic quality indices are used. The developed in Poland vibroacoustic reciprocity principle, inversion methods and assessment indices are not only used for the acoustic assessment of machines and objects but also for the identification of vibroacoustic energy sources, which is relevant to limiting the vibroactivity of sources and to the application in diagnostics.

Investigations and analyses of vibroacoustic processes were carried out by researchers within the realisation of the research project [G5] entitled: „Modern investigation methods of vibroacoustic processes in technical systems and objects - the comparative analysis”. During the realisation of this project several investigations concerning applications of the reciprocity and inversion methods in the vibroacoustic processes analyses were performed. These investigations were based on the previous investigations of the authors carried out in the AGH, University of Science and Technology, concerning the application of the inversion and reciprocity methods in vibroacoustics. The study comprises the theoretical analysis, investigations under laboratory conditions as well as under actual technical conditions. The methods which can be used in the vibroacoustic analysis of machines and devices were developed. Especially valuable is showing the possibility of applying inversion methods under actual industrial conditions. Based on the performed comparative analysis of the reciprocity and inversion methods, the areas of their applicability were shown. The developed and described methods can serve several purposes, among others: identifications of vibroacoustic energy sources, diagnostics and investigations of buildings e.g. sacral objects. Due to the realisation of this research project the monography: 'Vibroacoustic processes - sources, investigations, analysis' was written, [M2].

In spite of several publications concerning vibroacoustics, not many works are devoted to vibroacoustic processes occurring in the life, work and leisure environment of human beings. In the monograph [M2], which is aimed to fill - at least partially - this gap, a special attention was directed towards methods of investigating vibroacoustic processes. First of all the methods developed by Prof. Zbigniew Engel and his coworkers, especially the reciprocity and inversion methods, were presented. Apart from these methods another ones, such as: the intensity, statistical energy analysis, finite elements method, boundary elements method, the wavelet analysis and the singular values decomposition (SVD), were presented in the study. In individual chapters of the monograph discussions of problems concerning vibroacoustic energy sources and their identification, transfer and transformation of vibroacoustic energy, modelling and synthesis in vibroacoustics are presented. The last chapter describes the applications and comparisons of the inversion and reciprocity methods which are interrelated. Several investigations of the same machines and devices were performed by various methods. One of the investigations, described in the monograph, concerns determinations of acoustic parameters of the power press by means of the reciprocity method as well as comparisons of the calculation results of the total acoustic power of this press carried out by the inversion method, reciprocity method and orientation *in-situ* for the same type of press. When the vibroacoustic reciprocity principle is applied the basic problem constitutes discretisation of the tested surface emitting acoustic energy and first of all the number of points (elementary surfaces) which are treated as monopole sound sources. The proper criteria of the surface discretisation, especially for cases when structures are of heterogeneous stiffness and masses are randomly distributed, are not developed until present. An application of inversion methods is related to the reproduction of solutions by means of certain functionals determined on the solutions sets or to the reproduction of operators describing tasks. The inversion tasks constitute the class of difficult problems since they are relevant to solving tasks not properly formulated in the Hadamard meaning. For their solutions various regularisations are applied, among others the Tichonow's regularisation. An essential problem is the selection of regularisation parameters, related to investigations of the particular technical systems.

Ad. 3.

Open-pit mines of mineral raw materials belong to objects bothersome for the environment. Their operations cause series vibroacoustic threats for the external environment as well as for the work stations in these mines. In several cases such industrial plants are localised in the vicinity of housing districts and also near nature reserves which causes than their operations are of the negative influence on the natural environment.

My scientific-research works concerning open-pit mines can be divided into three trends, such as: (i) investigations of vibroacoustic threats sources, (ii) acoustic climate of open-pit mines of mineral raw materials and the sustainable development, (iii) concepts of antinoise protections.

- ***Investigations of vibroacoustic threats sources***

Sources of vibroacoustic hazards in opencast mines of rock materials can be divided into two groups. The first one constitutes machines and devices, taking part in the realisation of the technological process, being sources of a continuous noise. The second group constitute blasting works with explosive materials, which are sources of an impulse noise (of a short duration). Acoustic investigations of machines and devices operating in open-pit mines - described in detail in paper [K15] - indicated that currently noise threats are significant since in such plants machines and devices are rather old and operate without any antinoise protections. Acoustic investigations of machines and devices operating in the open-pit andesite mine were presented at the conference [K7], and then published in paper [P2]. Due to the results obtained - under actual industrial conditions - the acoustic pressure levels followed by acoustic power levels of such machines as: crushers, screens, belt conveyors, loading bins, were estimated. Investigations indicates high noise levels, in several cases exceeding the permissible values. They have a negative influence on the acoustic climate at the mine, but first of all they constitute a direct thread for these machines operators.

The problem of assessing occupational risks related to noise hazards at the selected work stations in open-pit mines was undertaken in paper [P9]. The risk assessing was performed for work stations situated near the most noisy devices, such as crushers. On the basis of the occupational risk in the three-steps scale, the risk is estimated as a large one. Only in one mine (on 3 tested) the work risk at the crusher is medium.

Investigations of impulse noises originated from blasting works were presented in paper [K16]. Blasting works are accompanied by high levels of acoustic pressures. Those are levels of the order 80÷100 dB for wall-blasting, while 90–130 dB for splitter-blasting. On the bases of the performed acoustic measurements exposure levels L_{AE} values for shootings were determined. The largest were in the place of explosions (110÷130 dB), while also high (L_{AE}=100 dB) were at the plant, which constituted threats for the employees. In areas of the nearest housing estates, being at a distance 1 km and 2 km from the plant, L_{AE} level was 70÷80 dB. The analysis of the spectrum of the source of this short-lasting noise indicates that low-frequency components dominate in the spectrum. It means that apart from hazards for inhabitants there is a negative influence on buildings and objects located in mining sites and in inhabited areas.

Investigations in the limestone opencast mine (published in paper [K26]) were the continuation of long-standing researches carried out in open-pit mines of andesite, dolomite and gypsum, described in paper [K17]. Sources of continuous noises, it means machines for limestone dressing into aggregates of various fractions, were the objects of vibroacoustic investigations. Noise levels in the excavator and loader cabins were recorded, accelerations of vibrations and noise levels at the mobile crusher deck, noise level at the crusher and screen (mobile machines) were measured. Acoustic power levels of the selected machines were determined as well as the estimation of noise and vibration hazards of mining machines operators was performed. Investigations showed that the mobile crusher operator is the most endangered, and that this machine requires the development and implementation of the proper antinoise protections.

Vibroacoustic hazards caused by exploitation of rock materials constitute a serious problem since more than 3300 mining enterprises, the so-called common mines, operate in Poland. In the majority of cases these are small enterprises, but often localised in the vicinity of housing estates. Vibroacoustic hazards depend on places and localisations, realised technological processes, applied machines and devices, kind of excavated material, etc.

- ***Acoustic climate of open-pit mines of mineral raw materials and the sustainable development***

Problems of the sustainable development[3] are more and more often attributed to the analysis of the vibroacoustic processes occurring in life and work environment of human beings [4,5].

It is possible to introduce such vibroacoustic indices occurring in work environment, which - from the one side - will be determining vibroacoustic hazard state and - from the other side - its reasons, together with efficient means of lowering hazards and improving the state called the acoustic climate[6]. The purpose of vibroacoustic indices is to reveal and record areas contaminated with noises, which means that they have to determine the acoustic climate of the natural and work environment.

The investigation and development of the estimation method of the acoustic climate in opencast mines of rock materials was one of the tasks realised within the research project [G6] entitled: „Designing of acoustic climate in opencast mines of rock materials as an element of the sustainable development", coordinated in years 2010-2013 by the Central Institute for Labour Protection – National Research Institute. The calculation procedure of the index method of the noise hazards estimation in opencast mines of rock materials was presented in paper [K28] and was preceded by tests shown in [K24]. The acoustic climate of an opencast mine of rock materials depends on several factors, out of which the main are acoustic parameters of machines and devices operating in an open space, their number and the way of installation. There are several work stations in such mine and they - as a whole - constitute the acoustic climate of the given mine. For the assessment of this climate quality the global index, being the approximate general measure and the function of some partial indices, can be introduced. Four partial indices were developed: the noise hazard index at the work station W_{HS}, impulse noise indicator W_{HI}, continuous noise indicator W_{HC} and sound power index W_{MA} [K28]. These indices, being components of the single-number global index W_{GKO}, allow to estimate the acoustic climate quality of the mine under testing, taking into account a man (W_{HS}), machine (W_{MA})

[3] Sustainable development is defined as the economic-social development, during which the integration process of political, economic and social operations occur, with retaining the nature equilibrium and stability of natural processes, in order to warrant possibilities of satisfying the basic needs of individual societies or citizens of the current and future generations. The concept of the sustainable development is based on creation of the indicators set, due to which it is possible to monitor and actualisation of the development strategy. Such idea gains nowadays more and more importance in various fields of science, technology and life.

[4] Z. Engel, W.M. Zawieska, *Noise Control at Workplace as an Element of Sustainable Development.* Proc. ICSV18, Rio de Janerio, 2011.

[5] A. Wawrzeńczyk-Zdżyłowska, W.M. Zawieska, *Problems of sustainable development in vibroacoustic analysis of the work environment (in Polish).* Bezpieczeństwo Pracy, 12, 10-13, 2011.

[6] The acoustic climate of the work environment can be defined as a system of acoustic effects occurring in this environment, generated by noise and vibrations sources and determined by the relevant acoustic parameters (partial indices), expressed as time, frequency space etc. functions.

and general acoustic conditions in the opencast mine of rock materials (W_{HC} and W_{HI}). The global index, W_{GKO}, proposed on the bases of the current investigations and analyses, in a similar fashion as partial indices, takes on the values from the range from 0 (very good acoustic climate) to 1 (bad quality of the acoustic climate, harmful influence on the mine staff). It is calculated from equation (10) in paper [K28] and takes into account the number of work stations and machines operating in the mine. The verification of the proposed index method was performed, within the research project [G6], in 1 opencast andesite mine. It was found, when analysing the acoustic climate by means of indices, that the calculated global index equals 0.2, which means a very good acoustic climate. Investigations performed when realising the research project indicated that the continuation of acoustic climate testing in more opencast mines of rock materials is advisable and that the influence of noise and vibroacoustic hazards not only on the work environment but also on the external environment should be considered. I still continue the investigations and analyses of vibroacoustic hazards in opencast mines.

- ***Concepts of antinoise protections***

As a result of many years standing research works carried out in opencast mines of rock materials such as andesite, dolomite, limestones, it was found that in smaller mines the mobile crushers constitute the highest noise hazards for employees. The equivalent sound A level, L_{Aeq}, at the work place usually exceeds the permissible value of 85 dB. The sound A level L_{Aeq} recorded during the crushing process was 104 dB [K9]. One of the tasks realised within the research project [G6] was the development of antinoise protections for this type of machines. Out of the analised, applicable antinoise protections, the portable acoustic baffles - relatively easy for the application - were proposed. They can be installed temporary at the mobile crusher just for its operation. This solution does not belong to the most efficient ones, nevertheless allows to apply it in practice and can constitute an essential contribution to improvement of safety and working conditions of employees of opencast mines of rock materials. The sound absorbing-insulating enclosure will be more efficient but it should be developed at the machine designing stage. Details of the performed investigations and analysis on antinoise protections were presented at the conference [K9] and published in study [P15]. Several simulation investigations carried out on the acoustic model of the machine combine (crusher-screen) were used for the prediction of the efficiency of the proposed antinoise solutions in a form of portable acoustic baffles. By means of this model the distribution of the equivalent sound A level around machines without any protections and with portable acoustic baffles, sound reflecting and sound absorbing, of various heights. The tests pointed out that the best improvement of the acoustic climate around the mobile crusher, operating in an opencast mine, will provide baffles 18 m long and 5 m high, overslung and sound absorbing [K9]. Preliminary analyses of the baffles efficiency - of an approximate character - were performed on the bases of simplified acoustic models of machines, containing individual omni-directional sound sources. More reliable results can be obtained on the bases of more accurate acoustic models of machines, which were developed within the 2nd stage of the research task [G6], with the inversion method application. The model of the combine system: crusher-screen, is based on 7 substitute sound sources of determined coordinates of the location of these sources. The detailed results of acoustic investigations of the mobile combine system crusher-screen performed by the inversion method under actual industrial conditions, are presented in paper [P3]. Simulation investigations with using such machine models, which can find the application at the development of antinoise protections of mobile crushers, require continuation of research in this direction.

The second developed concept of antinoise protections constitute screens of the operating field of mobile crushers, presented in study [P15]. In this case the existing reclining cover of the control cubicle was modified by laying out its internal part by mineral wool (5 cm thick) covered by a glass veil. Additionally, the application of the second reclining sound absorbing-insulating screen was recommended. This screen should be made of plexiglass or policarbonate (8÷10 mm thick) and shaped in a way enabling its closing together with the sound absorbing-insulating screen. Such solution has to provide an improved acoustic comfort for the machine operator.

Another main noise source in opencast mines of rock materials are blasting works which occur relatively seldom, however are characterised by high levels of acoustic pressures. One of the experiments performed by the researchers in the opencast andesite mine was an application of worn rubber belts from belt conveyors flights as antinoise lining on the rock being blasted by explosive materials. The experiment results were discussed at the conference [K6] and presented in paper [P15]. The obtained noise level decrease (L_{AE} - exposition level (SEL) with a weighting filter A), at the distance of 60m from the explosion place, was equal 6 dB.

The obtained investigation results have also a practical aspect. The developed conceptions of antinoise protections, which designers and practitioners dealing with the environment protection could apply, should finally limit noise hazards of employees of opencast mines of rock materials.

6. Summary of scientific-research activity

My published scientific achievements - up to the present - contain **52** papers, including **39** after receiving the doctoral degree in technical sciences. Out of all papers <u>published after receiving the doctoral degree:</u>

- **10** were published in journals from the JCR list (**7** of them had the Impact Factor in the year of publishing; I am the only author of **6** papers which are in the JCR list),
- **7** papers were published in the reviewed scientific Polish journals,
- **20** papers were published in the international and Polish conference proceedings,
- **2** studies constituted co-authoring of monographs.

In addition, 1 paper was sent for publication in the journal from the JCR list[7].

The list of published scientific papers divided into periods before and after receiving the doctorate degree, together with the Impact Factor index and MNiSW points, is given in Annex 6.

[7] K.Kosała, B.Stępień, *Analysis of noise pollution in an andesite quarry with use of simulation studies and evaluation indices, International Journal of Occupational Safety and Ergonomics (JOSE), 2014, the article submitted, currently - after two positive reviews.*

The obtained investigation results I presented at **9** international conferences:

1. The *4th* International Conference on Sacral and Monumental Buildings, 2002, Białystok
2. The *5th* International Conference on Sacral and Monumental Buildings, 2004, Białystok
3. Forum Acusticum, 2005, Budapest
4. The *6th* International Conference on Sacral and Monumental Buildings, 2006, Białystok
5. Thirteenth International Congress on Sound and Vibration (ICSV13), 2006, Vienna
6. 33rd International Acoustical Conference – EAA Symposium, 2006, Strbske Pleso
7. 14th International Conference on Noise Control, 2007, Elbląg
8. The *9th* International Scientific-Technical Conference: Designing problems in the context of new building technologies, 2011, Kraków
9. 16th International Conference on Noise Control, 2013, Ryn

19 local conferences:

1. The *30th* Winter School of Vibroacoustic Hazards Eliminations, 2002, Ustroń
2. The *49th* Open Seminar on Acoustics (OSA), 2002, Stare Jabłonki
3. The *31st* Winter School of Vibroacoustic Hazards Eliminations, 2003, Szczyrk
4. The *50th* Open Seminar on Acoustics (OSA), 2003, Szczyrk
5. The *51th* Open Seminar on Acoustics (OSA), 2004, Gdańsk
6. The *33rd* Winter School of Vibroacoustic Hazards Eliminations, 2005, Ustroń
7. The *34th* Winter School of Vibroacoustic Hazards Eliminations, 2006, Ustroń
8. The *53rd* Open Seminar on Acoustics (OSA), 2006, Zakopane
9. The *13th* Scientific Conference on Vibroacoustics and Vibrotechniques and the *8th* All-Poland Seminar on Vibroacoustics in Technical Systems: WibroTech, 2007, Jachranka
10. The *15th* Conference of Acoustic and Biomedical Engineering, 2008, Zakopane
11. The *55th* Open Seminar on Acoustics (OSA), 2008, Szklarska Poręba/Piechowice
12. The *13th* Symposium of Structure Dynamics - DYNKON, 2008, Bystre
13. The *15th* Scientific Conference on Vibroacoustics and Vibrotechniques and the *10th* All-Poland Seminar on Vibroacoustics in Technical Systems: WibroTech, 2010, Sękocin Stary
14. The *58th* Open Seminar on Acoustics (OSA), 2011, Jurata
15. The *40th* Winter School of Vibroacoustic Hazards Eliminations, 2012, Szczyrk
16. The *19th* Conference of Acoustic and Biomedical Engineering, 2012, Zakopane
17. The *16th* Scientific Conference on Vibroacoustics and Vibrotechniques and the *11th* All-Poland Seminar on Vibroacoustics in Technical Systems: WibroTech, 2012, Kraków
18. The *20th* Conference of Acoustic and Biomedical Engineering, 2013, Zakopane
19. The *60th* Open Seminar on Acoustics (OSA), 2013, Polańczyk

and **4** scientific seminars:

1. Seminar in the Central Institute of Labour Protection – National Research Institute (CIOP-PIB) in Warszawa on: "Singular Value Decomposition – SVD", 30.01.2008.
2. Seminar in Department of Vibroacoustics and Biodynamic Systems in Poznań University of Technology on: "Singular Value Decomposition at the example of acoustic assessment of temples", 09.06.2008.

3. Seminar in Department of Mechanics and Vibroacoustics in AGH University of Science and Technology in Kraków on: “Singular Value Decomposition at acoustic quality assessment of temples”, 11.01.2010.
4. Seminar on: „New solutions in terms of investigations and limiting vibroacoustic hazards”, in the Central Institute of Labour Protection – National Research Institute (CIOP-PIB) in Warszawa titled: „Antinoise protections for selected machines used in opencast mines of rock materials”, 03.09.2013.

According to the Web of Science base the Hirsch index equals **3**, and the total number of citations equals **22** (**10** – without autocitations). According to the Scopus base the total number of citations equals **37** (**14** – without autocitations) and the Hirsch index equals **4**. The list of publications which have citations together with papers in which these citations are written, is presented in Annex 9.
I participated in **5** research projects financed by the Committee for Research Projects – Ministry of Science and Higher Education (1 was the supervisor’s grant) and in **1** research project financed by the Ministry of Labour and Social Policy. I was either a contractor or a main contractor in these projects.
I was the reviewer of **8** papers sent for publication in journals from the JCR list (in years 2012-2014): Archives of Acoustics (5) and Acta Physica Polonica A (3). In the year 2014, I was the editor of Number 125 of Acta Physica Polonica A.
The cumulative list of information concerning my research-scientific achievements is given in the Table below:

Quantitative a summary of achievements of scientific research with evaluation indicators

ACHIEVEMENTS OF SCIENTIFIC RESEARCH			Before Ph.D.	After Ph.D.	TOTAL
PUBLISHED SCIENTIFIC WORKS					
Type of publication		Scores MNiSW[1)]			
Articles all together		267	5	17	22
	Articles from JCR list (source: Web of Science)	190	–	10	10
	Individual articles from JCR list (source: Web of Science)	110	–	6	6
	Articles not in the JCR list	81	5	7	12
Conference materials all together		–	8	20	28
	National conference materials	–	5	14	19
	International conference materials	–	3	6	9
Monographs (co-authorship)		40	–	2	2
TOTAL		**307**	**13**	**39**	**52**
PARTICIPATION IN CONFERENCES AND SCIENTIFIC SEMINARS					
International papers			2	7	**9**
National papers			5	14	**19**
Scientific seminars			–	4	**4**
PARTICIPATION IN PROJECTS					
KBN/MNiSW			4	1	**5**
MPiPS				1	**1**
OTHER RESEARCH ACTIVITY					
Reviews articles for journals from JCR list			–	8	**8**
INDICATORS OF SCIENTIFIC ACHIEVEMENTS					
Hirsch index (according to Web of Science)			–	3	**3**
Number of citation of publications (according to Web of Science)			–	22	**22**
Number of citation (Scopus)			1	36	37

[1)] Scoring of journals according to the actual list of MNiSW (of the year 2013) and scoring of monographs according to the Regulation of the MNiSW from July 13, 2012 concerning criteria and procedures of awarding scientific category to scientific units.

Scientific papers authored or co-authored by me, developed in the period after receiving the doctoral degree, were published in the scientific journals being in the Journal Citation Reports base. The total Impact Factor equals **4.518**.

The list of journals in the Journal Citation Reports database together with the Impact Factor

Journal (according to JCR)	Year of publication	Impact Factor (in agreement with the year of publication)
Archives of Acoustics	2007	–
Archives of Acoustics	2007	–
Archives of Acoustics	2008	–
Archives of Acoustics	2009	0.313
Archives of Acoustics	2011	0.847
Archives of Acoustics	2012	0.829
Applied Acoustics	2013	1.068
Acta Physica Polonica A	2013	0.604
International Journal of Occupational Safety and Ergonomics (JOSE)	2013	0.253
Acta Physica Polonica A	2014	0.604*
The total Impact Factor		**4.518**

* with taking into account the Impact Factor from 2013

Summary of scientific journals, with taking into account current score MNiSW, in which articles published to date were my authorship or co-authorship, is given in the table below.

Summary of scientific journals with score MNiSW

Journal	Current score MNiSW	Number of publications	Number of points
Applied Acoustics (JCR)	25	1	25
Archives of Acoustics (JCR)	20	6	120
International Journal of Occupational Safety and Ergonomics - JOSE (JCR)	15	1	15
Acta Physica Polonica A (JCR)	15	2	30
Archives of Acoustics	20	1	20
Diagnostyka – Diagnostics and Structural Health Monitoring	7	2	14
Czasopismo Techniczne *(in Polish)*	6	1	6
Kwartalnik Mechanika *(in Polish)* [later Mechanics, currently: Mechanics and Control]	5	4	20
Bezpieczeństwo Pracy, Nauka i Praktyka *(in Polish)*	5	3	15
Aura *(in Polish)*	2	1	2
Total:		**22**	**267**

For scientific achievements in the year 2009 I received AGH UST Rector the 3-rd degree award.

7. Didactic activity

The beginning of my didactic activity took place in the Department of Mechanics and Vibroacoustics AGH University of Science and Technology, where as a student of the last year of Master of Engineering studies I was a trainee assistant, and I had teaching classes of *Mechanics*. Auditorium classes from this subject, for the IMiR Faculty students leading to examinations I carry on up to now.

Being an assistant in the Department of Mechanics and Vibroacoustics I delived (in years 2003–2005) lectures on *Bases of Informatics* for students of full-time courses of the IMiR Faculty of AGH UST.

As an assistant professor, apart from *Mechanics,* since the year 2006, I have the auditorium and laboratory classes for students of the full-time studies in the IMiR Faculty of AGH UST in the subject of: *Theory of Mechanisms and Machines.*

Since the year 2013 I am delivering lectures, finished with examinations, for the full-time and evening students of the IMiIP Faculty, AGH UST in the subject: *Technical mechanics and strength of materials* and for the full-time students in the subject *Technical Mechanics.*

8. Organisational activity

From the very moment of starting my scientific work I participate in organisational activities related to actual operations of the Department of Mechanics and Vibroacoustics, AGH University of Science and Technology. I participated in studies financed by the Statute Research Fund concerning the topic: „Prediction and experimental investigations of new structures in acoustic adaptation of buildings".

In the years 2009–2010 I was the member of the Commission of Students Scientific Associations, AGH UST and actively participated in this Commission operations.

During the years 2006–2012 as the member of the Recruitment Commission of the Faculty of WIMiR AGH UST, I took an active participation in the Commission works.

In the years 2010 and 2013 I was the member of the organisational committee of the international Conferences on Noise Control and the co-chairman of the scientific session (in 2013). These Conferences are organised by the Central Institute of Labour Protection – National Research Institute (CIOP-PIB) in Warszawa with the cooperation of the Department of Mechanics and Vibroacoustics, AGH UST.

Since September 2014, I hold the supervisor position of the Team of New Materials and Solutions in Reduction of Vibroacoustic Hazards operating in the Department of Mechanics and Vibroacoustics, AGH UST.

The detailed list of my scientific-research, didactic, organisational and popularizing achievements is given in Annex 6.

REMARK: Notation symbols of publications not being a part of the scientific accomplishment corresponds with notations acc. to Annex 6.

30.09.2014 .... Krzysztof Kosała ....

Date Signature