Appendix 2

AUTOREFERAT

1. Name: Ph.D., Eng., Agnieszka Derewońko

2. Diplomas, academic degrees - including name, place and year of acquisition and the title of the doctoral dissertation.

2004 the degree of Doctor of Philosophy in technical sciences, specialty: technical mechanics, Department of Mechanical Engineering, Military University of Technology, the title of Ph.D. Thesis: Numerical analysis of contact stresses in the bolted joints in the case of the landing gear, supervisor Prof., D.Sc., Eng., Marian Dacko.
1986 M.Sc., Eng., in the field of mechanics, specialty: mechanical equipment, Faculty of Mechanical Engineering and Technology, Warsaw University of Technology.

3. Information concerning previous employment in scientific / artistic units

Place of employment:

Department of Mechanics and Applied Computer Science,
Faculty Of Mechanical Engineering
Jaroslaw Dabrowski Military University of Technology
2 General Sylwester Kaliski str.,
00-908 Warsaw 49

Employment history:

Since 2005 Assistant Professor at the Faculty of Mechanical Engineering, Jaroslaw Dabrowski Military University of Technology, Warsaw.
1993 - 2004 Asistant at the Faculty of Mechanical Engineering, Jaroslaw Dabrowski Military University of Technology, Warsaw.
1986-1991 constructor at the Department of Research and Development Personal Lifts Plant "Zremb", Warsaw.

4. Indication of research achievement resulting from the Art. 16 Paragraph/item 16. 2 of the Act dated 14 March 2003 on academic degrees and academic title as well as on the degrees and title in the scope of art (Journal of Laws No. 65, item 595, as amended)

a) Monothematic series of publications titled "**Application of computer methods of mechanics to the interaction of deformable bodies**" I have regarded it as a basis to initiate habilitation procedure as understood in the Act dated 14 March 2003 on Academic Degrees and Title and on Degrees and Title in the art (Journal of Laws No 65, item . 595 as amended.). The selection includes 16 author's and co-author's publications.

List of publications forming a monothematic series titled "**Application of computer methods of mechanics to the interaction of deformable bodies**":

- Riveted joints
H1. Derewońko A., Szymczyk E., Jachimowicz J., 2006, *Numeryczne modelowanie zagadnienia kontaktu w procesie spęczania nitu*, Biuletyn WAT, vol. LV 4(644), s. 89-100, MNiSW 6, 50%.
H2. Derewońko A., Szymczyk E., Jachimowicz J., 2006, *Analiza połączenia nitowego z uwzględnieniem naprężeń resztkowych i eksploatacyjnych*, Górnictwo Odkrywkowe, 5-6, s.114-117, MNiSW 6, 50%.

H3. Szymczyk E., **Derewońko A.**, Jachimowicz J., 2006, *Analysis of displacement and stress distributions in riveted joints*, III European Conference on Computational Mechanics Solids, Structures and Coupled Problems in Engineering, Mota Soares A., Martins J. A. C., Rodrigues H. C., Ambrosio J. A. C., Pina C. A. B., Mota Soares C. M., Pereira E. B. R., Folgado J. (eds.), 2006, LXXIV, 788 p. DOI: 10.1007/1-4020-5370-3_434, z nośnikami CD, Springer Netherlands, MNiSW 2, 30%.
H4. Derewońko A., Szymczyk E., Jachimowicz J., 2007, *Numeryczne szacowanie poziomu naprężeń resztkowych w zakuwanym połączeniu nitowym*, Monografia zbiorowa pt.: „Analizy numeryczne wybranych zagadnień mechaniki", red. T. Niezgoda, rozdz. 17, s. 329–350, Warszawa, MNiSW 3, 40%.
H5. Szymczyk E., Jachimowicz J., **Derewońko A.**, Sławiński G., 2010, *Analysis of microslips and friction in the riveted joint*, Diffusion and Defect Data Pt.B: Solid State Phenomena, 165, pp. 388-393, MNiSW 20, **IF 0,337**, 15%.
H6. Derewońko A., Sławiński G., Szymczyk E., Jachimowicz J., 2008, *Modelowanie wybranych zagadnień dynamicznych*, Transport Przemysłowy, 2, 32, s. 22-27, MNiSW 6, 50%.
H7. Sławiński G., **Derewońko A.**, Jachimowicz J., Niezgoda T., Szymczyk E., 2010, *Numeryczna symulacja dynamicznego procesu spęczania nitu grzybkowego z kompensatorem*, Biuletyn WAT vol. LIX, NR 1, str. 61-74, MNiSW 9, 40%.

- Adhesive joints
H8. Derewońko A., Niezgoda T., Godzimirski J., 2006, *3D Numerical Investigation of Tensile Loaded Lap Bonded Joint of Aircraft Structure*, Journal of KONES Powertrain and Transport, vol. 13, no. 3, s. 61-68, MNiSW 6, 70%.
H9. Niezgoda T., **Derewońko A.**, Kosiuczenko K., 2007, *Badania wytrzymałości klejowego połączenia zakładkowego*, Prace Naukowe PW Seria Mechanika, z.217, s. 97-102, MNiSW 2, 60%.
H10. Derewońko A., Godzimirski J., Kosiuczenko K., Niezgoda T., Kiczko A., 2008, *Strength assessment of adhesive-bonded joints*, Computational Materials Science, vol. 43, Is. 1, pp. 157-164, MNiSW 24, **IF 1,674**, 50%.
H11. Derewońko A., Gieleta R., 2007, *Numeryczne i eksperymentalne badania wytrzymałości połączeń klejowych*, Zeszyty Naukowe Politechniki Świętokrzyskiej. Nauki Techniczne, Z. 4, s. 23--24, 50%.
H12. Derewońko A., 2009, *Prediction of the failure metal/composite bonded joints*, Computational Materials Science, vol. 45, Is. 3, pp. 735-738, MNiSW 24, **IF 1,713**.
H13. Derewońko A., Gieleta R., 2012, *Carbon-Epoxy Composite Fatigue Strength – Experiment And Fem Numerical Estimation*, Journal of KONES Powertrain and Transport, Vol. 19, No. 3, pp. 103-110, MNiSW 9, 50%.
H14. Derewońko A., Gieleta R., 2008, *Numerical analysis of the metal-composite joint*, Journal of KONES Powertrain and Transport, 15, 1, s. 39-50, MNiSW 6, 70%.
H15. Gieleta R., **Derewońko A.**, 2007, *Fatigue strength investigation of bonded joint*, Journal of KONES Powertrain and Transport, 14/3, s. 177-186, MNiSW 6, 50%.
H16. Derewońko A., Gieleta R., Kosiuczenko K., 2008, *Analiza numeryczna połączenia śrubowego kompozytu warstwowego z metalem*, Kompozyty (Composites), 2, s. 185-189, MNiSW 6, 60%.

Total **impact factor** of journals, which published a series of monothematic articles is **3.724**. Number of points on the basis of Ministry of Science and Higher Education list is **135**. Both indices rates were calculated for the year the magazine journal release year.

My substantive contribution to co-authors publications usually consisted in defining issues, setting objectives and methodology of numerical analyses and formulating conclusions. My percentage participation in collaborative publications is given in Table 1 which also contains a detailed presentation of my contribution to the publications. The range of co-authors participation is attached to the application as Appendix 5.

Table 1 My contribution to the following publications

No. of work	Contribution	Participation %	Coauthor's signature
H1	Development of assumptions of the method for mapping the rivet upsetting process and the conditions of interaction, of a tool and the front surface of the cylinder. Determination of the effect of the type and the shape of the finite elements on stress and strain. Modelling of the rivet upsetting process and conducting numerical analyses. Interpretation of the results and formulating conclusions. Editing the work.	50%	E. Szymczyk J. Jachimowicz
H2	Development of a method for creating a local numerical model of the rivet joint with the concept of mapping the interaction of bodies in contact, modelling the rivet upsetting process and conducting numerical analyses. Formulating the conclusions. Editing the work.	50%	E. Szymczyk J. Jachimowicz
H3	Formulation of the FEM model assumptions of the rivet upsetting process on the power press. Development of a method for mapping the technological conditions and the conditions of interaction of bodies in contact. Numerical analyses of rivet joints. Determination of the relative deformations on the level of residual stresses induced by the process of upsetting the rivet on the power press. Formulating the conclusions.	30%	E. Szymczyk J. Jachimowicz
H4	Formulation of assumptions. Development of conditions of interaction of bodies in contact. Numerical analyses of rivet joints. Analytical calculations and verification of the obtained results. Formulating the conclusions. Editing the work.	40%	E. Szymczyk J. Jachimowicz
H5	The initial formulation of the problem. Development of methodology for mapping the interaction of bodies of small thickness described in Micro-local model part. Determination of the influence of the method of modelling two bodies with different stiffness. Determination of models of the cladding material. Formulating the preliminary conclusions.	15%	E. Szymczyk J. Jachimowicz G. Sławiński
H6	Development of a method of dynamic cylinder upsetting. Selection of a finite element type, a calculation procedure and development of a method to determine the conditions of interaction between the tool and the front surface of the cylinder. Development of method of modelling of connecting two sheets with a mushroom head rivet, which enables to take into account the conditions of interaction of bodies in contact during the dynamic process of upsetting the rivet. Development of options of transferring energy in the process of upsetting the rivet. Formulation of the preliminary conclusions.	50%	E. Szymczyk J. Jachimowicz G. Sławiński
H7	Development of a method of nonlinear quasi-static analysis of creating connecting of two sheets with a mushroom head rivet in the dynamic rivet upsetting process. Selection of a finite element type and a calculation procedure. Development of a method to determine the conditions of interaction between the parts of the joint. Formulation of the preliminary conclusions.	40%	E. Szymczyk J. Jachimowicz G. Sławiński T. Niezgoda
H8	Determination of the assumptions of the problem. Development of a method for nonlinear, quasi-static analysis of uniaxial tensile test of an adhesive lap joint including the secondary bending moment. Development of a three-dimensional model of the adhesive lap joint. Defining the areas of interaction. Formulation of the conclusions. Writing the publication.	70%	J. Godzimirski T. Niezgoda

H9	Development of a method for tests and numerical analyses of metal to metal adhesive joints. Conducting the numerical analyses with the selection of parameters of the contact. Verification of the results. Writing the publication and formulating the conclusions.	60%	.... T. Niezgoda .... K. Kosiuczenko
H10	Development of methods for three-dimensional modelling of collaboration of the components of the adhesive joint including the secondary bending moment and with the ability to visualize the destruction. Selection of material models. Development of methodology of visualization of joint destruction. Comparison of the results of numerical analyses and experimental research. Formulating and writing the article, except point 3.1, and formulating the conclusions.	50%	.... J. Godzimirski .... K. Kosiuczenko .... T. Niezgoda .... A. Kiczko
H11	Development of visualization methods of joint destruction. Developing a model of the discrete adhesive-bonded joint using Gurson-Tvergaarda-Needleman equation, which includes a hydrostatic part of a stress tensor.	50%	.... R. Gieleta
H13	Development of a method for the durability analysis of the multilayer composite, including the interlayer shear, using computer methods.	50%	.... R. Gieleta
H14	Development of method of tests and numerical analyses of various types of metal adhesive joints with a composite. Selection of a method of modelling the composite. Conducting nonlinear, quasi-static numerical analyses. Writing the publication and formulating the conclusions.	70%	.... R. Gieleta
H15	Formulation of assumptions. Development of methodology for numerical analyses of fatigue strength of the tensile joint of a multi-layer composite with metal, taking into account the secondary bending. Carrying out numerical analyses. Writing the publication and formulating the conclusions.	50%	.... R. Gieleta
H16	Development of the methodology for determining the temporary and fatigue strength of bolted joints of the composite adhesive joint with metal joints using FEM. Determination of fatigue characteristics of the materials of the joined parts. Carrying out numerical analyses. Writing the publication and formulating the conclusions.	60%	.... R. Gieleta .... K. Kosiuczenko

Some publications formulating a series are cited in the works published in Polish and foreign publishing houses. Table 2, compares the publications, specifying the impact factor of journals in which the publications formulating a series are cited. The list does not include author's citations. The first column contains the number of the publication formulating a series.

Table 2 Citations of articles from a series of monothematic publications

No.	Citations
H3	1 Jachimowicz J., Wronicz W., 2008, *Wybrane problemy modelowania nitowanych, lotniczych struktur cienkościennych*, Przegląd Mechaniczny ROK WYD. LXVII ZESZYT 5. 2 Mańkowski, J. Osiński J., Rumianek P., 2010, *Proposal For The Method Of Determining The Most Intensive Fragments Rivet Joins Appearing The Shell Air Panels Working Under The Influence Of Tension Field*, DIAGNOSTYKA' 3(55). 3 Szymczyk E., Sławiński G., 2010, *Influence of Material Model on Tensile Loaded Joint*, Solid State Phenomena 165, 394, pp. 394-399, **IF 0,493**.
H4	4 Jachimowicz J., Kozłowski P., Moneta G., Szymczyk E., Kaniowski J., 2010, *Zjawisko frettingu w konstrukcjach lotniczych*, Prace Instytutu Lotnictwa 4 (206), ilot.edu.pl.
H5	5 Bedair O., *Stress field characteristics of eccentrically loaded aircraft spliced joint*, Applied Mathematical Modelling, **IF 1,265**.
H10	6 Fedele R., Rakab B., Hildb F., Roux S., 2009, *Identification of adhesive properties in GLARE assemblies using digital image correlation*, Journal of the Mechanics and Physics of Solids, 57, 1003-1016, **IF 3,231.** 7 Ferreira M.D.C., Venturini W.S., Hildb F., 2011, *On the analysis of notched concrete beams: From measurement with digital image correlation to identification with boundary element method of a cohesive model*, Engineering Fracture Mechanics, vol. 78, Is. 1, pp. 71–84, **IF 0,976.**

	8 Wei Xu, Yueguang Wei, 2012, *Strength analysis of metallic bonded joints containing defects*, Computational Materials Science, vol. 53, Is. 1, pp. 444–450, **IF 1,107.** 9 Morin D.; Haugou G.; Bennani B.; Lauro F., 2011, *Experimental Characterization of a Toughened Epoxy Adhesive under a Large Range of Strain Rates*, Journal of Adhesion Science and Technology, vol.25, Nr 13, pp. 1581-1602(22), **IF 0,508.** 10 Yasar A., 2011, *Effect Of Adhesive Geometry On The Tensile Properties Of Aisi 1350 Steel*, METALURGIJA 50 1, 67-70; METABK 50(1) 67-70, **IF 0,309.** 11 Aldas K., Sen F., Palancıoğlu H., 2011, *Stress Analysis Of Adhesively Bonded And Pinned Single Lap Joints Using Three Dimensional Finite Element Models*, Journal of Theoretical and Applied Mechanics, Sofia, vol. 41, No. 2, pp. 3–20**.** 12 Aldas K., Palancıoğlu H., Sen F., 2009, *Thermal stresses in adhesively bonded double lap joints by FEM*, Electronic Journal of Machine Technologies Vol: 6, No: 4, (55-64). 13 Aldaş, K., and Sen, F., 2011, *Stress Analysis Of Hybrid Joints Using Different Materials via 3d-Fem*, International Journal of Engineering & Applied Sciences (IJEAS) Vol.3, Is. 1, pp.90–101. 14 D. Morin, G. Haugou, B. Bennani, F. Lauro, 2013, *Characterization of a structural adhesive by Digital Image Correlation*, Application of Imaging Techniques to Mechanics of Materials and Structures, Volume 4, Conference Proceedings of the Society for Experimental Mechanics Series, 2013, Volume 14, 107-115, DOI: 10.1007/978-1-4419-9796-8_14, Springer. 15 D. Morin, G. Haugou, F. Lauro and B. Bennani, 2011, *Elasto-viscoplasticity behaviour of a structural adhesive under compression loadings, Dynamic Behavior of Materials*, vol. 1, Conference Proceedings of the Society for Experimental Mechanics Series, 369-377, DOI: 10.1007/978-1-4419-8228-5_55 Springer New York. 16 Comer, A.J., Katnam K.B., Stanley W.F., Young T.M., 2012, *Characterising the Behaviour of Composite Single Lap Bonded Joints using Digital Image Correlation*, International Journal of Adhesion and Adhesives, Available online 28 August 2012, http://dx.doi.org/10.1016/j.ijadhadh.2012.08.010, MNiSW 27, **IF 2,170**. 17 Şen F., Adlaş K., Palancıoğlu H., *Yapıştırıcı Tekniği ile Alüminyum Bağlantıların Analizi*, http://www.bilesim.com.tr/yazdir.php?t=3&id=7796&sn=0, 14.06.2012.
H12	18 Jumel, J., Budzik, M.K., Shanahan, M.E.R., *Process zone in the Single Cantilever Beam under transverse loading. Part I: Theoretical analysis*, Theoretical and Applied Fracture Mechanics 56 (1) , pp. 7-12, 2011, **IF 0,771**. 19 Ribeiro M.L., Angélico R. A., Tita V., *Investigation Of Failure Analysis On Single And Double Lap Bonded Joints*, 2009 Brazilian Symposium on Aerospace Eng. & Applications; 3rd CTA-DLR Workshop on Data Analysis & Flight Control, September 14-16, 2009, S. J. Campos, SP, Brazil. 20 Ribeiro M.L., Angélico R. A., Tita V., *Development Of A Computational Tool For Bonded Joint Analysis*, Proceedings of PACAM XI; 11th Pan-American Congress of Applied Mechanics - PACAM XI, 2010.

The total **impact factor** of journals, in which the publications from the series are cited, is **10.337** and has been calculated for the journal release year.

The monothematic series of publications contains articles published in journals from a "Philadelphian list of journals" (ISI Master Journal List), Polish scientific journals and international publishing houses. I popularized the results of my research in **69 publications**. The results of scientific research published after obtaining the degree of Doctor of Philosophy in technical sciences, were used in structures that were the subject of patent applications and were presented at numerous innovation exhibitions, which I listed in Annex 4.

b) presentation of the research target of the works mentioned above and the achieved results with presentation of their possible use

My achievement, as understood in the Act dated 14 March 2003 on Academic Degrees and Titles and on Degrees and Title in the art (Journal of Laws No 65, item. 595, as amended.), is a series of monothematic publications titled "**Application of computer methods of mechanics to the interaction of deformable bodies**".

Computer aided methods of mechanics and CAE software are a very effective tool to solve complex scientific and engineering issues, what I documented in numerous papers published both before and after the defence of my Ph.D. thesis. However, it is a mathematical description and it is required to adopt simplifying assumptions, especially in analyses of interaction of deformable bodies. Such problems are found in many structures including rivet and adhesive joints.

Riveting is, to date, a basic type of permanent joints used in producing constructions of light alloys. It is widely used in the construction of airplanes and helicopters. Riveted joints are the place of stress concentration, where residual stresses are generated in the very riveting process.

The initial phase of the study concerning riveted joints comprised searching for the method enabling the analysis of a single rivet upsetting process using computer methods of mechanics. Accurate mapping of an industrial upsetting process, helped choose the three-dimensional finite elements, a description of the material and the method of modeling contact problems with friction between a tool and leading frontal surfaces of the compressed sample **[H1]**. The maximum value of axial force is estimated analytically using the method of balance of work, according to the formula $P_2 = A_1 \sigma_{pk} \left(1 + \frac{\mu}{3} \frac{2r_0}{l_0} \right) = 70933{,}8\ N$. Change of the value of the axial force as a function of the way of the stamp, obtained from numerical analysis, corresponds to the one obtained from industrial experiences similarly as the obtained maps of total strain. The value of upsetting force from the numerical calculations is 3% lower than the one calculated theoretically. However, the average stresses along the axis of the rivet shank are 4% greater than the analytical values. In modeling of the joint: rivet shaft - sheet, the choice of the finite element mesh in the contact area is focused, which will ensure smooth deformations (no penetration of nodes) and, thereby, the lack of non-physical stress concentrations in the contact area.

Large-scale modeling was used to simulate the tensile test of a specimen made of two aluminum sheets and six steel conical rivets **[H2]**. It allowed reduction of the computation time and adjust the size of the model to the hardware capabilities.

The developed and validated ~~a~~ three-dimensional model of the rivet and one sheet was the basis for the mapping phase of the upsetting of the rivet joining two aluminum sheets on the power press. The distance between the edge of the hole and the outer edges of the sheets, in which the rivet is fixed, is about 4 times greater than the initial diameter of the rivet. Such a model enables to avoid the impact of the boundary conditions in accordance with the *de Saint Venant* principle. In the contact areas of the joint, there was applied a dense distribution mesh, which was loosed in the direction of the outer edge of the sheet. There were identified seven areas of contact in deformable bodies, such as a rivet and sheet metal. The eighth area is a rigid body mapping the tool. It is assumed that there occur friction between the contact areas.

Rivet upsetting consists in forming a head as a result of deformation of the rivet shaft caused by operation of the rivet snap. After closing the rivet, the rivet snap is removed. The numerical model also simulated the process in two stages:

- Stage I - a rigid body displacement by a certain value;
- Stage II - relieving the rivet (removing the rivet snap).

A global model was developed for the upset sample. Shell elements with a regular shape were used to map the shape of the sheets. Models of rivets and heads were developed with rigid (RBE2) and contact (GAP) elements of right stiffness. Application of GAP elements enabled mapping of cooperation of rivets and plates with taking friction into consideration. In both cases, numerical analysis was carried out in the elastic-plastic range, taking large displacements and deformations into account, assuming three - segmental isotropic models with strengthening of the rivet and sheets materials.

During the operation of airplanes and helicopters as well as in studies of other elements of thin-walled structures, there are observed many phenomena occurring in the surrounding of rivets, such as plastic deformation, frictional fatigue (fretting), fatigue fracture, etc., which adversely affect the durability of the connection causing the initiation of coating fracture **[H3]**.

A developed discrete three-dimensional model allows a description of the phenomena in the interaction of contacting objects that have been mentioned above. Mapping of the contact surface with two sets of nodes allows analysis of displacements (slip) of the rivet surface in respect to the surface of the rivet hole in the package of sheets as well as to determine the influence of residual stresses remaining in the rivet upsetting process on the level of stresses caused by loads originating during the service life of the structure. It also allows determination of strain and stress areas in the surrounding of the rivet and place of occurrence of their maximum values. The exact location of extreme stress differences indicates a possible point of initiation of microcracks and the occurrence of fretting.

By dint of the nature of the studied fretting phenomenon, the sheets were made of D16 aluminum alloy while the rivet is made of St3S steel. Such an unconventional selection of materials causes acceleration of the destruction process of the sheets surfaces, what reduces time-consumption of experimental strength tests. Numerical modelling of experimental studies required consideration of the problem in which there occur simultaneously both physical non-linearity, resulting from the contact of two bodies, and geometrical nonlinearity, the source of which is the elastic-plastic constitutive model introduced in the form of strengthening curves for the rivet and sheets materials. Application of quasi-static nonlinear multiscale analysis allowed determination of, among others, contact stresses and stress distribution in all parts of the joint for different load levels **[H4]**. Estimating these values and deformations of bodies in interaction is not possible using experimental methods.

Aluminum sheets applied in aircraft constructions are clad on both sides, that is, thin coatings of different or the same metals are applied on the core material. Coating thickness is about 5% of the total thickness of the sheet. The developed local model of aluminum rivet, made of PA25, alloy connecting the two clad sheets, made of D16TN aluminum alloy, helped define stress and strain distributions and relative displacements of the joint components in the areas of contact. The values of radial stresses in the hole area were compared with the experimental results showing satisfactory agreement. The verified numerical model of an upset joint was subjected to tensile loading, causing mutual displacements of connected plates **[H5]**.

Determination of the coefficient of friction in contacting sheets, particularly clad layers covering the core of sheets, requires preparation of a micro-local model. It is composed of two cuboids placed one upon the other. Clad layers in contact, representing the lower and upper part of blocks, are 60 micrometers thick and present mechanical properties of clad. Residual stresses in the sheets after rivets upsetting are generated by applying a normal load to the top surface of the upper cuboid. The load ~~it~~ stops working before the movement of the upper block begins, which is implemented by applying a cyclic horizontal displacement of the value determined in the analysis of the local model.

Calculation procedure consists of three repeated steps:

- Calculation of contact pressure and relative displacement,
- Calculation of nodes displacement and growth of the rate of wear,
- Upgrading the coordinates of nodes.

A micro-local discrete model allows determination of the depth of deformation (the value of the vertical strains) of clad layers, the contact stress distribution, plastic part of the rate of wear and a coefficient of friction. Simulations of the rivet upsetting on the power press was conducted using the procedures for quasi-static non-linear calculations.

Similarly as in the case of upsetting on the power press, simulations of the dynamic riveting process started from the cylinder upsetting, analyzing the problem of energy transfer from the rivet snap to the frontal part of the cylinder, under given conditions of contact with friction **[H6]**.

In the riveting process, finite elements of the mesh within the head undergo large deformations, and, in the result, it is necessary to take into account a component dependent on the history of the load in the stiffness matrix. Since determination of possible sources of nonlinearity depends on the analyzed object, and, above all, on the applied type of finite elements, implementation of large deformations is related to the definition of the element. Application of dynamic analysis, taking into account nonlinear components of Lagrange- Green strain tensor allows you to find non-linear response of the system to load. In this case, eight-nodes solid elements with eight integration points were used to build the discrete models of a mushroom head rivet and both joined sheets. Tool and rounded tool were modeled as rigid bodies. The study also showed differences resulting from the way of mapping the tool.

In the case of dynamic riveting, the initial stress remaining in sheets after the riveting process depends on the method of forming the head **[H7]**. Therefore, a simulation of the process of dynamic riveting of rivet head with compensator was conducted using, among others, a so-called simple method of riveting. This method consists in the fact that a tool strikes the shank end of the rivet, while the rounded tool is pressed to the rivet head. Simulations were performed using the LS-Dyna. These analyses include also material nonlinearities and contact with friction phenomena.

The rivet upsetting process was realized by ascribing mass and initial kinetic energy specified in the standard to plate describing tool. Riveting resulted from one stroke. In the initial phase of the riveting, as a result of a tool heavy impact into the shaft, there occurs a gap between the factory rivet head and the bottom sheet of package. It is a consequence of deformation of the compensator on the stationary tool. In the subsequent phases, as a result of deformation of the rivet, the gap disappears. The total time of head formation was about 0.8 ms.

Another example of the interaction of deformable bodies are adhesive-bonded joints. Adhesive are widely applied in automotive, marine and aviation industries. Development of a safe and effective adhesive joint requires a good knowledge of the influence of mechanical properties and geometrical design on strength and durability of the joint.

The mechanism of bonding depends on:

- adhesion of glue to the piece, where adhesion, that is, force occurring at the interface of two materials is a very important factor.
- strength within the adhesive, which is provided by the cohesion, that is, forces operating between the molecules of the adhesive and maintaining its integrity.

In the adhesive joint, forces of adhesion and cohesion should be equal. The exact description of numerical analyses and experimental tests of metal to metal adhesive-bonded joints is shown in **[H8]** and **[H9]**. The study was performed for samples of adhesive lap joints in accordance with the standards in which the adhesive layer thickness was 10% of thickness of the jointed sheets. The samples were prepared from two plates of PA7T aluminum alloy bonded with Epidian 57.

Mechanical properties of both the materials were determined from experimental studies. While the aluminum curve was obtained in a standard tensile test of flat shoulder specimens, the parameters defining nonlinear properties of the adhesive were obtained from the compression test. The compression test was conducted for a sample cured under conditions corresponding to forming of the weld of the tested lap joint. The compression test of the adhesive enables determination of these properties to a greater extent than the tensile test. The result of the conducted experiment was obtaining the force-displacement characteristic and the value failure force.

The adhesive lap joint has been subjected to the uniaxial tensile test. Non-axial character of mounting of the adhesive joint in the jaws of the machinery-was modelled in numerical analyses with the use of two-stage loading:

- Step 1 – loading with secondary bending moment,
- Step 2 – loading with tensile force.

A three-dimensional model of the sample was built of eight-node cubicoid elements. The adhesive weld is modelled with the use of two layers of finite elements. Due to the thickness of the parts that are in the interaction, while generating elements the mesh was thickened in the area of the corners, i.e., in the location of the expected stress concentration, and it was loosen in the central part of the joint reducing, at the same time, the size of the computational model **[H10]**. All the surfaces of interaction were separate sets of nodes. This approach allows the plot of contours lines of, for example, shear stress on the contacting surfaces of the adhesive and the lap.

If the hypothesis that the adhesive strength of adhesive joints is associated with their resistance to tearing is taken for granted, then adhesive destruction of the adhesive joints depends on the value of a normal positive stresses. Since all the surfaces of interaction were separate sets of points, it was possible to apply a special method of mapping contact problems. During the implementation of the calculation procedure, ~~the~~ after detection of contact between the corresponding nodes of two contacting objects, constraints are automatically formed. The equations of these constraints are in the given form $\Delta u_{normal} = v \cdot \mathbf{n}$, $\Delta u_{styczne} = v \cdot \boldsymbol{\tau}$, where: n, τ - normal and tangential vectors, v - relative velocity **[H11]**.

It allows the determination of reaction forces and contact stresses. The introduction of boundary values of the contact normal stress leads to separation of corresponding nodes, allowing the visualization of the destruction process of the joint and the presentation of results of analyses, for example, in the form of graphs of stresses along the center lines of the joint.

Adhesive destruction of the adhesive joint is the process in which the local stress concentrations occur on bonding surfaces. Depending on the joined materials, they may be treated as a crack initiator. Physical relationships of isotropic material models are based on the Huber-Mises-Hencky Yield Criterion, taking into account only the existence of the deviatoric part of the stress tensor. This relationship describes behaviour of metallic laps material. A material model, in which some voids exist, was ascribed to the elements of an adhesive layer. In this model, the hydrostatic part of the tensor is described by the Gurson physical equation that was modified by Tvergaard and Needleman **[H12]** and **[H13]**.

Adhesive joint strength depends on, among others, the strict observance of manufacturing technology, such as surface preparation. Therefore, in the subsequent models, the existence of voids (detachments) was assumed in the contact area between the surface of the upper lap and adhesive. The results of numerical analyses can be presented in the form of, for example, ~~as~~ vectors of normal contact stresses. Determination of normal contact stresses allows visualization of the joint deformation caused by the growing external load. It is also possible to indicate locations of local stresses concentrations caused by the detachment of the adhesive from the joined material, in the initiation of fracture is possible to occur. Application of quasi-static, non-linear calculation procedure allows determination of these areas in a function of external load of the sample.

Knowing the difference in the elastic strain energy of contacting surfaces, it is possible to determine the coefficient corresponding to the ratio that, in the fracture mechanics, is defined as the intensity of the released strain energy: $G = \frac{d\Pi}{da}$, where Π is the energy of deformation, a - the length of the crack. The obtained results clearly indicate the influence of modeling the contact surfaces on strain energy of the bonded surfaces. In the case of modeling the contact area with separate sets of nodes, the strain energy is higher.

Application of the Gurson-Tvergaard-Needleman model for numerical modelling of adhesive allows not only investigation of the influence of insufficient bonding occurring on the contact surface detachments but also simulation of cohesive failure of adhesive and failure of bonded materials. This is especially useful in the case of bonded composite structures whose material parameters depend significantly on the technology of their manufacturing.

The presented method of analysis of behavior of adhesive joints allows mapping of the actual tests conducted for those joints made from various materials such as multilayer composites. It was also necessary to develop a method of composites modeling, which would allow consideration of interlayer failure **[H14]**, **[H15]** and **[H16]**.

Special, three-dimensional eight-node finite elements were used to build a model of the composite. The mathematical description of such an element considered the existence of up to 520 layers of the composite layers with different thicknesses, orientations, and material properties. The values of stresses and strains are determined in the four Gauss points located in the middle of thickness of a single layer. Uniaxial tension and compression test were applied to, among others, 14 layered samples made of laminated carbon-epoxy composite. The individual layers were characterized by different orientations of position of the warp fibers in respect of the direction of loading.

Methods developed in numerical analyses of adhesive metal to metal joints were used for simulation of the tensile tests of metal-composite samples: single and double-lap as well as double-lap with a screw

Orthotropic material properties were ascribed to composite layers. An intermediate model, where each layer forming the laminate is treated as a homogeneous body, ~~it~~ is applied to describe forms of structural failure. Failure criteria applied in the program are formulated and written in the space of stress (strain) in the local coordinates system of a single layer of laminate for the flat state of stress. The criterion of the maximum allowable stress was used in the analyses. The results of the simulation, which set out the damage indexes for the laminate are verified by experimental results. Numerical analysis also allowed to estimate the levels of loads and areas for which the initiation of structural damage occurs.

Methods developed for simple types of adhesive joints were utilized in the simulations, of metal-composite structural element called the fitting. A composite structure of carbon preimpregnat was stuck to the metal part in the form of stairs.. These studies included static tests with strain measurements at characteristic points of the fitting, and fatigue tests. Comparison of the results of numerical analyses and the results tensile tests showed satisfactory agreement.

All types of adhesive joints were subjected to both experimental and numerical fatigue tests. Introduction of SN curves (describing the stress amplitude in the function of a number of cycles to failure) determined experimentally helped accurately estimate the locations of the lowest fatigue life of the joints. As expected, these are the boundary edges of the adhesive joints.

The scientific achievements I consider essential is development of the principles and methods applying computer methods in mechanics in selected analyses of deformable bodies, particularly, determination of conditions of interaction of two bodies, taking into account the objects of varied thicknesses and compliances with the use of multiscale modelling.

The experience obtained during implementation of the above presented monothematic series of publications H1-H16 has been used to design the structures whose solutions are protected and have been made public in a European patent

1 EP 2 251 255 A sectional ponton bridge, inventors: Niezgoda T. 80%, Krasoń W. 10%, **Derewońko A.** 5%, Bogusz P. 5%,

and in Polish and European patent applications compared below:

2 P388739, WIPO ST 10 C PL388739, Pontonowy most kasetowy, inventors: Niezgoda T. 80%, Krasoń W. 10%, **Derewońko A.** 5%, Bogusz P. 5%.

3 P395311, WIPO ST 10/C PL395311, Zespół zamków mechanicznych do łączenia kaset mostu pływającego oraz mechanizm otwierania kasety, inventors: Niezgoda T. 50%, Krasoń W. 20%, **Derewońko A.** 20%, Chłus K. 5%, Popławski A. 5%.

4 EP12171708, A cassette of a floating bridge, inventors: Niezgoda T. 50%, Krasoń W. 20%, **Derewońko A.** 20%, Chłus K. 5%, Popławski A. 5%.

5 P.392851, Wielofunkcyjna osłona balistyczna, inventors: Niezgoda T. 50%, **Derewońko A.** 30%, Sławiński G. 20%.

Design solutions developed using methods published in the works of **H1-H16** received awards at Polish and international exhibitions of innovations that have been collected in the list below. The awards were organized chronologically.

1 Silver medal, 100th International Exhibition of Inventions Concours Lepine, Paris 2010, Cassette Pontoon Bridge.

2 Bronze Medal, 59th International Exhibition of Inventions, Research and New Technologies "Brussels INNOVA 2010, Brussels 2010, Multi-purpose ballistic protection.

3 Silver Medal, 4th International Warsaw Invention Show IWIS 2010, Warsaw 2010, Cassette Pontoon Bridge.

4 Bronze Medal, 4th International Warsaw Invention Show IWIS 2010, Warsaw 2010, Multi-purpose ballistic protection.
5 Silver Medal, International Exhibition of Ideas - Innovation - New Products IENA, Nuremberg 2010, Multi-purpose ballistic protection.
6 Gold Medal at the International Invention Fair in Seoul, SIIF 2010, South Korea., Cassette Pontoon Bridge.
7 Bronze medal at the International Warsaw Invention Show IWIS 2011, Cassette Pontoon Bridge.
8 DEFENDER Award at the 20th International Defence Industry Exhibition in Kielce MSPO 2012 by Pontoon bridge deck.

The construction of a cassette pontoon bridge designed with the use of the methods published in works **H1-H16**, was, in the years 2009 to 2011, the subject of research and development project of Ministry of Science and Higher Education PBR/15-333/WAT/2009 titled "Development of flexible modules and materials with high strength and ballistic resistance for the use in the crossing bridges" completed with a report on the implementation.

The industrial partner in the consortium implementing the project stated its intention to use the executed construction in production.

5. Presentation of other scientific - research achievements

I obtained a degree of Doctor of Philosophy in Technical Sciences after the submission of the thesis entitled “Numerical analysis of contact stresses in the bolt connections in the case of the landing gear” supervised by Professor, D.Sc., Eng., Marian Dacko. Before I defended my Ph.D. dissertation, I published 18 publications in the form of articles and conference papers. I listed them at the end of Annex 4.

In my Ph.D. dissertation I proposed a method of mapping the contact problem in bolt joints, which enables also consideration of a variety of structural factors such as friction, or clearances. I presented a way of estimating the stiffness of GAP beam elements, which allows avoiding of numerical difficulties in obtaining the correct solution. The presented concept of modelling of a pin joint is universal and can be used in any geometric configuration resulting from mutual rotating of the parts of the machine set. The described method of modelling of the pin joint was applied for numerical analysis of Skytruck landing gear. These analyses were carried out within the framework of the research project entitled "Numerical method for determining low-cycle fatigue strength of cooperating elements of landing gear", ordered by the State Committee for Scientific Research. The team of the Committee assessed the final report along with a report on the implementation of this work and gave it an excellent opinion.

My experience in the field of contact problems analyses was used during my work on projects, within which framework the publications forming a presented above monothematic series were written.

The subject matter of application of computer methods in the a analyses of mechanics of deformable bodies interaction proved to be very important in the design of the cassette pontoon bridge, whose integral part is a pneumatic carrying object (PON), with a variable volume. This problem was the subject of my intensive research over the past three years. At the same time, it was necessary to develop a method for determining the properties of coated fabrics, from which PON are made, what is proved by works collected in the "List of achievements in scientific research work" which is Appendix No.4 to the “Habilitation application”.

Some of problems which I worked on after the defense of my Ph.D. thesis I considered the basis for the initiation of the habilitation procedure. My monothematic series of publications includes only the publications that, in the best way, present the subjects I specialize in.

I presented a monothematic list of publications in Section 4. I listed there also articles that have been cited the impact factor (IF) of the journal publishing these articles. Table 3 presents a summary list of publications after obtaining a Ph.D. degree from divided according to the type of their publicizing.

Table 3 List of publications released after obtaining a Ph.D. degree

Type of publication	The number of publications	The number of citations
Chapter in a Polish-language monograph	1	
Authorship or co-authorship of scientific publications in journals in the included Journal Citation Reports (JCR) database	8	6
Authorship or co-authorship of scientific publications in journals included in Scopus database	9	7
Authorship or co-authorship of scientific publications in journals included in a list of Ministry of Science and Higher Education	25	
Authorship or co-authorship of scientific publications in international conferences materials	17	
Authorship or co-authorship of scientific publications in Polish conference materials	17	
Number of publications before Ph.D.	18	

The total **impact factor** of scientific publications according to the Journal Citation Reports (JCR) list, in accordance with the year of publication is **3.922**. Number of points of journals, in which the articles were Publisher, based on the **list of Ministry of Science and Higher Education,** is **276**.

Number of citations of publications according to the Web of Science (WoS) database **7**, and using the "Publish or Perish" **30**. These numbers do not include own citations.

Hirsh index according to the Web of Science (WoS) database 1, and using the "Publish or Perish" h-index = 3.

After obtaining a Ph.D. degree , I managed **two** projects and I was an executive in at least **12** research and development projects.

Together with my co-workers I was honoured with a diploma of the Rector of Military University of Technology and received numerous awards at international scientific conferences.

Publications, of which I was the author or co-author were delivered at **27 international conferences and 11 national conferences**. I took an active part in 16 international conferences and 7 national conferences. I was invited to chair a session titled Modelling and Simulation Tools and Techniques for the IASTED International Conference on Applied Simulation and Modelling (ASM 2011), 22-24 June 2011, Crete, Greece. I am also a member of the Scientific Committee of the 38th International Scientific Congress on Powertrain and Transport Means.

In addition, for 7 years I was a member of the Organizing Committee of the Scientific and Technical Conference "MSC Programs in Computer Aid for Analysis of Design and Manufacturing" organized by the Department of Mechanics, presently Department of Mechanics and Applied Computer Science, Faculty of Mechanical Engineering, Military University of Technology.

For my achievements and contributions, I was awarded with the title of Distinguished Academic Teacher of Military University of Technology and with state awards.

I managed the development project No. O R00 0079 09 implemented by a consortium, including, among others, Military Engineering Plant in Deblin.

I am a member of Polish and international scientific and professional societies.

For twenty years I have been running classes and laboratory exercises with students, and, after obtaining a PH.D. degree, I also deliver lectures at my alma mater. I teach, among others, engineering mechanics, strength of materials and CAE software. I prepared my own academic curricula of several leading subjects of the Department of Mechanics and Applied Computer Science. I prepared teaching materials in the form of brochures available in the Laboratory of Mechanics Computational Methods and at the website of the Department of Mechanics and Applied Computer Science, Faculty of Mechanical Engineering, Military University of Technology. In the last three years, I was a tutor of 3 engineering theses and 2 master's theses. Since 2009 I have been performing the function of the year tutor subsequently for year: V, I and III. I was a tutor of seven foreign students undergoing scientific trainings at Military University of Technology in 2003 and 2004.

I am a scientific tutor of one Ph.D. student.

I took part in a three-month training in Pipetronix GMBH company in Toronto, Canada. The training concerned the strength of the transmission pipeline with the use of an intelligent multi-purposed piston raised by the flowing liquid.

I use my research and design experience in, for example, expert service for PARP (Polish Agency for Enterprise Development). In 2010, within the framework of measure 1.4-4.1 "Support for special projects and support for implementation of results of R & D" OPIE, to the order of the Polish Chamber of Commerce for High Technology, I reviewed the report of the implemented project. I wrote some English-language reviews of articles for journals published by, among others, worldwide scientific publisher Elsevier.

I have been coordinating the field of patent protection in the Department for four years. I applied for a grant under the Patent Plus programme for patent applications. The grant was awarded.

I presented a detailed list of all my achievements in the "List of achievements in scientific research work" which is Appendix No 4 to the "Habilitation application".

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signature of the Applicant