

CURRICULUM VITAE

Name: Alfred Zmitrowicz

Areas of expertise & research interests:

- Modelling of friction and wear of materials.
- Structural dynamics.
- Continuum mechanics and thermodynamics.

Details of education:

- D Sc (habilitation) in mechanics, Institute of Fluid-Flow Machinery, 11 January 1994.
- Ph D in engineering sciences, Institute of Fluid-Flow Machinery, 6 February 1980.
- M Sc in civil engineering, Gdańsk University of Technology, 24 October 1973.

Career to date:

- Associate Professor, Institute of Fluid-Flow Machinery, 1994-present.
- Assistant Professor, Institute of Fluid-Flow Machinery, 1980-1994.
- Senior Research Assistant, Institute of Fluid-Flow Machinery, 1975-1980.
- Research Assistant, Institute of Fluid-Flow Machinery, 1973-1975.

International research experience:

- Research Fellow in SFB No. 298, Institut für Mechanik III, Technische Universität Darmstadt, Germany, December 2001.
- Alexander von Humboldt Scholarship, Institut für Mechanik III, Technische Universität Darmstadt (by Prof. Kolumban Hutter), Germany, September - November 2001.
- Alexander von Humboldt Scholarship, Institut für Mechanik (Bauwesen), Universität Stuttgart, Germany, May – September 1991.
- Alexander von Humboldt Scholarship, Institut für Mechanik (Bauwesen), Universität Stuttgart (by Prof. Hans Bufler), Germany, August 1984 – January 1986.
- Research Scholarship, Institute of Mechanics, Yerevan, Armenia; Institute for Problems in Mechanics, Moscow, Russia; Institute on Problems of Strength, Kiev, Ukraine; February – March 1981.
- IAESTE Training, Port of Helsinki Authority, Finland, June – August 1973.

Memberships of associations:

- Societas Humboldtiana Polonorum, member 1989-present, Member Main Supervisory Board 2016-present, Member Executive Council 2007-2013, Vice-President Gdańsk Branch 2014-2016, Treasurer Gdańsk Branch 2000-2014.
- Mechanics of Materials Section of the Committee on Mechanics of The Polish Academy of Sciences, member 1994-present.
- Polish Society of Theoretical and Applied Mechanics, member 1978-present.

Awards and honours:

- Gold Medal for Long Service, The President of Poland, Warsaw 2016.
- “Laurel of the Societas Humboldtiana Polonorum” from the Scientific Society Societas Humboldtiana Polonorum, Poznań 2013.
- “Sint sua praemia laudi” Medal, The Pomerania Province Governor, Gdańsk 2006.
- Gold Cross of Merit, The President of Poland, Warsaw 1991.

- Research Fellow of Alexander von Humboldt Foundation, Germany, Bonn 1984.
- Scientific Secretary Award from The Polish Academy of Sciences, Warsaw 1982.
- Prof. Witold Wierzbicki Award from The Polish Society of Civil Engineers and Technicians, Warsaw 1973.

Conference session organizer (together with Prof. R. Buczkowski and Prof. P. Litewka):
 Minisymposium “Wear and Friction - Analytical and Numerical Approaches”, ETAMM 2018, Kraków 2018; Minisymposium “Contact Mechanics”, PCM-CMM-2015, Gdańsk 2015; Minisymposium „Contact Mechanics”, 20th CMM Conference, Poznań 2013; Minisymposium „Computational Contact Mechanics”, 18th CMM Conference, Zielona Góra 2009.

Conference session chairman:

ETAMM 2018, Kraków 2018; PCM-CMM-2015, Gdańsk 2015; Humboldt-Colloquium, Toruń 2015; 20th CMM Conference, Poznań 2013; Euromech No. 514, France, Cargèse 2012; Humboldt-Colloquium, Gdańsk 2011; 8th International Congress SHP, Toruń 2010; 18th CMM Conference, Zielona Góra 2009; 80th GAMM Jahrestagung, Gdańsk 2009; Humboldt-Colloquium, Toruń 2008; 36th Solid Mechanics Conference, Gdańsk 2008; IUTAM Symposium, Germany, Hannover 2006; GAMM Jahrestagung, Kraków 1991.

Reviewer:

Journals: Acta Mechanica, Advances in Mechanical Engineering, Computational Mechanics, International Journal for Numerical Methods in Engineering, International Journal of Solids and Structures, Iranian Journal of Science and Technology - Transactions of Mechanical Engineering, Journal of Mechanics of Materials and Structures, Key Materials Engineering, Mechanical Systems and Signal Processing, Proceedings of the Institution of Mechanical Engineers: Part C, Proceedings of the Royal Society A, Structural and Multidisciplinary Optimization, Scientific Reports, Strojniški vestnik (Journal of Mechanical Engineering), Tribology in Industry, Wear, ZAMM, Archives of Civil and Mechanical Engineering, Archives of Mechanics, Bulletin of the Polish Academy of Sciences – Technical Sciences, Engineering Transactions, Journal of Theoretical and Applied Mechanics, Tribologia, Zagadnienia Eksploatacji Maszyn, TASK Quarterly, Technika Morska, Zeszyty Naukowe Politechniki Gdańskiej, Modelowanie Inżynierskie, Polska Bibliografia Analityczna Mechaniki.

Books: Wiley, Wydawnictwo Politechniki Poznańskiej.

Administrative activities:

- Head of the Doctoral Studies in Institute of Fluid-Flow Machinery (the third level education in mechanical engineering), 2011- present,
- Coordinator of the Baltic Science Festival in Institute of Fluid-Flow Machinery (an annual even designed to promote scientific achievements), 2008 - 2015.

Main research results:

- Variations of friction and wear with respect to sliding directions (anisotropy) and with respect to positions on sliding trajectories (non-homogeneity) are observed in materials with complex microstructures and/or with evolving mechanical properties e.g. in single crystals, composites, layer-lattice materials, polymers, ceramics, biomaterials and monomolecular layers. I have formulated constitutive equations for anisotropic and inhomogeneous friction force, wear rate and frictional heat flux. Linear and nonlinear, centrosymmetric and non-centrosymmetric phenomenological models of anisotropic friction and wear have been developed, as well as first- second- and higher-order

descriptions of heterogeneous friction and wear with respect to sliding path curvatures. Various types of frictional anisotropy are distinguished with the aid of friction tensors and symmetry groups, i.e. isotropy, orthotropy, full anisotropy, axi-symmetry, unidirectionality, trigonality, tetragonality. Various types of frictional heterogeneity are classified with respect to shapes of sliding trajectories, i.e. concentric circles, rays emanating from the origin, Archimedean spiral, lemniscate of Bernoulli. In the frame of continuum thermodynamics, the constitutive equations satisfy the axiom of objectivity, and restrictions on parameters of the constitutive equations follow from the second law of thermodynamics.

- Results of abrasive wear are identified as irreversible changes of shapes and sizes of contacting and rubbing solids and as an increase of a clearance gap between elements. Furthermore, the mechanism of wear involves formation of loose wear particles detached from the bodies. Various constitutive models describe quasi-solid, quasi-fluid and granular-like behaviour of the wear particles. I have developed models and simulations of the abrasion process. Differential forms of governing equations (mass continuity, motion and heat conduction) are constructed from general balance laws (within the frame of continuum mechanics). Variational formulations applied to contact problems are extended by taking into account the interfacial layer of wear particles, and by including an increase of the clearance gap due to the abrasive wear process. The bodies and the interfacial layer are discretized by means of finite elements. The wear debris transmit loads and displacements at the contact interface, and they affect frictional and wear behaviour of materials significantly.
- In mechanical systems, the frictional interaction of contacting surfaces has a dominant influence on dissipation of energy and damping of vibrations. It plays a crucial role in turbines where resonant vibrations cannot be avoided. I have performed simulations of vibrations of turbine blade assemblies with isotropic and anisotropic friction in interfaces of non-continuous shroud rings. A slow increase of harmonic forced vibration amplitudes in resonant conditions have been achieved by the proper selection of friction parameters between the shroud ring segments.

Publications

1. A. Zmitrowicz, Modeling of polymer friction on boundaries of solids and inside materials, *Materials*, 2021, 14(20), 6187.
2. A. Zmitrowicz, A multiscale approach to friction on surfaces of polymeric solids and in bulk polymeric materials, In WCCM-ECCOMAS2020. 14th World Congress on Computational Mechanics (WCCM) and ECCOMAS Congress 2020. Virtual Congress: 11-15 January 2021, F. Chinesta, R. Abgrall, O. Alix and M. Kaliske (Eds). Available online https://www.scipedia.com/public/Zmitrowicz_2021a
3. A. Zmitrowicz, Thermodynamics: main concepts and stages of development. Part 1, 2, 3, 4, *Fizyka w Szkole*, no. 4, 357(LXIII), lipiec/sierpień 2018, pp. 16-21; no. 5, 358(LXIII), wrzesień/październik 2018, pp. 12-16; no. 6, 359 (LXIII), listopad/grudzień 2018, pp. 18-23; no. 1, 360(LXIV), styczeń/luty 2019, pp. 9-15 (in Polish).
4. A. Zmitrowicz, An analysis of wear processes of materials based on variational methods, *Mathematics and Mechanics of Solids*, 23(3), 2018, 504-518.

5. A. Zmitrowicz, Physical secrets of the strength of materials. Part 1, 2, *Fizyka w Szkole*, no. 6, 347(LXI), listopad/grudzień 2016, pp. 10-17; no. 1, 348(LXII), styczeń/luty 2017, pp. 16-24 (in Polish).
6. A. Zmitrowicz, Development of friction constitutive relations for polymers, In *Advances in Mechanics: Theoretical, Computational and Interdisciplinary Issues, Proceedings of the 3rd Polish Congress of Mechanics & 21st International Conference on Computer Methods in Mechanics* (PCM-CMM 2015), September 8-11, 2015, Gdańsk, Poland, (eds. M. Kleiber et al.), CRC Press/Balkema (Taylor & Francis Group), London 2016, pp. 623-626.
7. A. Zmitrowicz, Why a mechanical engineer needs geometry? Part 1, 2, 3, *Matematyka*, no. 6, 407(LXVII), czerwiec 2014, pp. 4-10; no. 7, 408(LXVII), lipiec/sierpień 2014, pp. 4-13; no. 9, 410(LXVII), październik 2014, pp. 2-12 (in Polish).
8. A. Zmitrowicz, Friction models of polymers at external boundaries of solids and inside the materials, In *Short Papers, CMM 2013, 20th International Conference on Computer Methods in Mechanics*, (eds. T. Łodygowski et al.), Poznań 2013, pp. MS 14-19, MS 14-20.
9. A. Zmitrowicz, Contact stresses: a review of models and methods of computations, *Archive of Applied Mechanics*, 80(12), 2010, 1407–1428.
10. A. Zmitrowicz, How glaciers move? *Fizyka w Szkole*, no. 6, 311(LVI), listopad/grudzień 2010, pp. 8-26 (in Polish).
11. A. Zmitrowicz, Monuments of mechanical engineering in Gdańska and surrounding, *Fizyka w Szkole*, no. 1, 306(LVI), styczeń/luty 2010, pp. 19-42 (in Polish).
12. A. Zmitrowicz, Three hundred years of the science of friction, *Fizyka w Szkole*, no. 3, 302(LV), maj/czerwiec 2009, pp. 4-18 (in Polish).
13. A. Zmitrowicz, Descriptions of contacts in the presence of wear debris, *PAMM – Proceedings in Applied Mathematics and Mechanics*, 9(1), 2009, 693–694.
14. A. Zmitrowicz, Contact models incorporating effects of wear debris, In *Short Papers, CMM 2009, 18th International Conference on Computer Methods in Mechanics*, (eds. M. Kuczma, K. Wilmański, W. Szajna), Zielona Góra, 2009, pp. 521-522.
15. A. Zmitrowicz, Contact mechanics of wearing out solids, In *IUTAM Symposium on Computational Methods in Contact Mechanics*, Series: *IUTAM Bookseries*, (eds. P. Wriggers, U. Nackenhorst), Springer, Dordrecht, 2007, pp. 311-331.
16. A. Zmitrowicz, Thermomechanics of wearing out solids, In *Proceedings of the First Polish Congress of Mechanics*, (eds. J. Kubik, W. Kurnik, W.K. Nowacki), Warsaw, 2007, pp.1-8 (in Polish).
17. A. Zmitrowicz, Models of kinematics dependent anisotropic and heterogeneous friction, *International Journal of Solids and Structures*, 43(14-15), 2006, 4407-4451.
18. A. Zmitrowicz, Wear patterns and laws of wear - a review, *Journal of Theoretical and Applied Mechanics*, 44(2), 2006, 219-253.
19. A. Zmitrowicz, Sliding path curvature dependent friction and wear, In *Analysis and Simulation of Contact Problems*, Series: *Lecture Notes in Applied and Computational Mechanics*, (eds. P. Wriggers, U. Nackenhorst), Springer, Berlin Heidelberg, 2006, pp.369-370.
20. A. Zmitrowicz, Models and applications of anisotropic and heterogeneous friction and wear, In *50 Years of the Institute of Fluid-Flow Machinery. Anniversary Book*, Gdańsk 2006, pp.288-291, (in Polish).
21. A. Zmitrowicz, Wear debris: a review of properties and constitutive models, *Journal of Theoretical and Applied Mechanics*, 43(1), 2005, 3-35.

22. A. Zmitrowicz, Evolutions of friction anisotropy and heterogeneity, In *Mechanics of 21st Century. Proceedings of the 21st International Congress of Theoretical and Applied Mechanics*, 15-21 August 2004, Warsaw, (eds. W. Gutowski, T.A. Kowalewski), Springer, Dordrecht 2005, CD-ROM, Paper No. SM2-11613.
23. A. Zmitrowicz, Wear debris and their constitutive equations, In *Transactions on Mechanics of Structures and Materials, Monografia No. 302*, Cracow University of Technology, Krakow, 2004, pp. 317-326 (in Polish).
24. A. Zmitrowicz, Glaciers and laws of friction and sliding, *Acta Mechanica*, 166(1-4), 2003, 185-206.
25. A. Zmitrowicz, Solution algorithms of contact problems with wear debris between sliding surfaces, In CD-ROM *Proceedings 15th Int. Conference on Computer Methods in Mechanics*, Gliwice/Wisła, June 3-6, 2003, (eds. T. Burczyński et al.), Publisher: Silesian Technical University, Gliwice, pp.1-10.
26. A. Zmitrowicz, Wear profiles and wear debris taken into account in variational approaches to contact mechanics, In *Proceeding Fifth World Congress on Computational Mechanics*, July 7-12, 2002, Vienna, (eds. H.A. Mang, F.G. Rammerstorfer, J. Eberhardsteiner), Publisher: Vienna University of Technology, pp. 1-10, <http://wccm.tuwien.ac.at>
27. A. Zmitrowicz, Variational descriptions of wearing out solids and wear particles in contact mechanics, *Journal of Theoretical and Applied Mechanics*, 39(3), 2001, 791-808.
28. A. Zmitrowicz, Strong and weak formulations of contact problems with various laws of friction, frictional heat and wear, *Machine Dynamics Problems*, 24(1), Warsaw 2000, 209-222.
29. A. Zmitrowicz, Variational approach to contact, friction and wear problems, *Zeitschrift für Angewandte Mathematik und Mechanik*, 80 (suppl, No.2), 2000, S463-S464.
30. A. Zmitrowicz, Variational formulations of contact, friction and wear problems, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 504/1463/99, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1999, 1-111.
31. A. Zmitrowicz, Vibrations of turbine blade assemblies with stick and slip conditions, In *IUTAM Symposium on Unilateral Multibody Contacts*, (eds. F. Pfeiffer, Ch. Glocker), Kluwer Academic Publishers, Dordrecht, 1999, pp.319-329.
32. A. Zmitrowicz, Illustrative examples of anisotropic friction with sliding path curvature effects, *International Journal of Solids and Structures*, 36(19), 1999, 2849-2863.
33. A. Zmitrowicz, An equation of anisotropic friction with sliding path curvature effects. *International Journal of Solids and Structures*, 36(19), 1999, 2825-2848.
34. A. Zmitrowicz, Constitutive modelling of non-homogeneous and anisotropic friction of materials – sliding path curvature effects, In *Computational Mechanics. New Trends and Applications*, (eds. S. Idelsohn, E. Oñate, E. Dvorkin), CD-ROM Proceedings, CIMNI, Barcelona, 1998, pp.1-21.
35. A. Zmitrowicz, A note on natural vibrations of turbine blade assemblies with non-continuous shroud ring, *Journal of Sound and Vibration*, 192(2), 1996, 521-533.
36. A. Zmitrowicz, Models of anisotropic friction depending on a sliding path curvature, In *Contact Mechanics*, (eds. M. Raous, M. Jean, J.J. Moreau), Plenum Press, New York, 1995, pp.343-346.
37. A. Zmitrowicz, Constitutive models for anisotropic frictional heat, *International Journal of Heat and Mass Transfer*, 38(3), 1995, 563-574.

38. A. Zmitrowicz, Constitutive modelling of anisotropic phenomena of friction, wear and frictional heat, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 381/1342/93, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1993, 1-234.
39. A. Zmitrowicz, Ein Beitrag zur Beschreibung der anisotropen Erscheinungen des Verschleißes und der Reibungswärme, In *Vortragsauszüge GAMM-Seminar über dem Kontakt fester Körper*, (eds. H. Bufler, P. Wriggers), Stuttgart, 1993, pp.2(1)-2(31).
40. A. Zmitrowicz, Constitutive equations for anisotropic wear, *International Journal of Engineering Sciences*, 31(3), 1993, 509-528.
41. A. Zmitrowicz, A constitutive modelling of anisotropic wear, *Zeitschrift für Angewandte Mathematik und Mechanik*, 72(4), 1992, T290-T292.
42. A. Zmitrowicz, Illustrative examples of centrosymmetric and non-centrosymmetric anisotropic friction, *International Journal of Solids and Structures*, 29(23), 1992, 3045-3059.
43. A. Zmitrowicz, A constitutive modelling of centrosymmetric and non-centrosymmetric anisotropic friction, *International Journal of Solids and Structures*, 29(23), 1992, 3025-3043.
44. A. Zmitrowicz, Natural vibrations of a turbine blade assembly with a non-continuous shroud ring, *Mechanika Teoretyczna i Stosowana (Journal of Theoretical and Applied Mechanics)*, 30(2), 1992, 333-357 (in Polish).
45. A. Zmitrowicz, Anisotropic friction models having central symmetry and without central symmetry, *Zeitschrift für Angewandte Mathematik und Mechanik*, 71(4), 1991, T332-T334.
46. A. Zmitrowicz, Linear and nonlinear constitutive equations of anisotropic friction, *Zeszyty Naukowe AGH. Mechanika*, 9(2), Cracow 1990, 141-154 (in Polish).
47. A. Zmitrowicz, On the thermodynamics of contact, friction and wear, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 287/1212/89, Publisher: Instytut Maszyn Przepływowych, Gdańsk, 1989, 1-190.
48. A. Zmitrowicz, Variables of constitutive equations for friction, wear and frictional heat in the light of experiments, *Technika Morska (Marine Technology Transactions)*, 1(1), Gdańsk 1989, 237-257.
49. A. Zmitrowicz, Mathematical descriptions of anisotropic friction, *International Journal of Solids and Structures*, 25(8), 1989, 837-862.
50. A. Zmitrowicz, A nonlinear model of frictional anisotropy, *Zeitschrift für Angewandte Mathematik und Mechanik*, 68(4), 1988, T269-T270.
51. A. Zmitrowicz, A thermodynamical model of contact, friction and wear: III constitutive equations for friction, wear and frictional heat, *Wear*, 114(2), 1987, 199-221.
52. A. Zmitrowicz, A thermodynamical model of contact, friction and wear: II constitutive equations for materials and linearized theories, *Wear*, 114(2), 1987, 169-197.
53. A. Zmitrowicz, A thermodynamical model of contact, friction and wear: I governing equations, *Wear*, 114(2), 1987, 135-168.
54. A. Zmitrowicz, A thermodynamical model of rubbing and wearing solids, *Zagadnienia Eksploatacji Maszyn*, 21(1/65), Warsaw 1986, 205-214.
55. A. Zmitrowicz, A thermodynamical model of contacting solids, In *Vortragsunterlagen GAMM-Seminar über Unilaterale Probleme*, (eds. H. Bufler, J. Gwinner), Stuttgart, 1984, pp. Zm(1)-Zm(21).
56. A. Zmitrowicz, A theoretical model of anisotropic dry friction, *Wear*, 73(1), 1981, 9-39.

57. A. Zmitrowicz, A vibration analysis of a turbine blade system damped by dry friction forces, *International Journal of Mechanical Sciences*, 23(12), 1981, 741-761.
58. A. Zmitrowicz, A vibration analysis of a blade assembly with taken into account a damping by friction forces in a non-continuous shroud ring, In *Proceedings 13th International Conference on Machine Dynamics*, Jadwisin n/Warsaw, 1981, pp.515-520 (in Polish).
59. A. Zmitrowicz, Vibrations of a turbine assembly damped by friction forces in interfaces of a non-continuous shroud ring, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 114/1022/81, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1981, 574-579 (in Polish).
60. A. Zmitrowicz, Vibrations of a rod system with Coulomb friction at a discontinuity surface, *Mechanika Teoretyczna i Stosowana*, 18(3), 1980, 475-505 (in Polish).
61. A. Zmitrowicz, On analysis of blade packed vibrations taking into account dry friction in a discontinuity surface of a bandage, In *Proceedings 4th Symposium on Structural Dynamics*, Rzeszów, 1979, pp.169-177 (in Polish).
62. A. Zmitrowicz, A numerical analysis of vibrations of a rod system with dry friction in a discontinuity surface, In *Proceedings 4th Conference on Computer Methods in Structural Mechanics*, Koszalin, 1979, pp.17-22 (in Polish).
63. A. Zmitrowicz, Motion equations of two rigid bodies contacting in a rough surface, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 33/923/78, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1978, 47-53 (in Polish).
64. A. Zmitrowicz, A description of Coulomb friction forces during a complex relative sliding of solids, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku. Studia i Materiały*, Vol. 33/923/78, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1978, pp. 54-60 (in Polish).
65. A. Zmitrowicz, Friction mechanisms in blade assemblies of turbines, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 45/919/78, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1978, 1-44. (in Polish).
66. A. Zmitrowicz, Coulomb friction forces during rotation, *Mechanika Teoretyczna i Stosowana*, 16(4), 1978, 584-600 (in Polish).
67. A. Zmitrowicz, Tensor of Coulomb friction, *Mechanika Teoretyczna i Stosowana*, 15(4), 1977, 517-527 (in Polish).
68. A. Zmitrowicz, Planar motion of two rigid bodies contacting in a rough line, Series: *Zeszyty Naukowe Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku (Studia i Materiały)*, Vol. 1/877/77, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1977, 1-40. (in Polish).
69. W. Pietraszkiewicz, M. Lidke, J. Wekezer, A. Zmitrowicz, Analysis of the spatial frame system with taking into account the effect of axial forces on the bending deformation of rods, *Rozprawy Inżynierskie (Engineering Transactions)*, 24(3), Warsaw 1976, 559-572 (in Polish).
70. A. Zmitrowicz, Selected problems of dry friction, Series: *Biuletyn Instytutu Maszyn Przepływowych Polskiej Akademii Nauk w Gdańsku*, Vol. 127/804/1975, Publisher: Instytut Maszyn Przepływowych, Gdańsk 1975, 1-80. (in Polish).

Conference contributions, invited talks, recognized seminar presentations
(read out in Polish, English, German and Russian)

1. A. Zmitrowicz, A multiscale approach to friction on surfaces of polymeric solids and in bulk polymeric materials, *14th World Congress in Computational Mechanics (WCCM) & ECCOMAS Congress 2020*, Virtual Congress: January 11-15, 2021.
2. A. Zmitrowicz, Sliding directions, sliding path curvatures and complex microstructures included in friction models of polymers, *Emerging Trends in Applied Mathematics and Mechanics 2018*, Jagiellonian University, Kraków 18-22.06.2018.
3. A. Zmitrowicz, Modelling of wear of materials in terms of variational methods, *8th Contact Mechanics International Symposium*, IPPT, Warsaw 11-13.05. 2016.
4. A. Zmitrowicz, Development of friction constitutive relations for polymers, PCM-CMM-2015, *3rd Polish Congress of Mechanics & 21st International Conference on Computer Methods in Mechanics*, Gdańsk 8-11.09.2015.
5. A. Zmitrowicz, Variational settings in mechanics of wear, *39th Solid Mechanics Conference*, Zakopane 1-5.09.2014.
6. A. Zmitrowicz, Friction models of polymers at external boundaries of solids and inside the materials, CMM 2013, *20th International Conference on Computer Methods in Mechanics*, Poznań 27-31.08.2013.
7. A. Zmitrowicz, Models of friction and wear of polymers: thermodynamic considerations, *Euromech Colloquium No. 514 "New Trends in Contact Mechanics"*, Cargèse (France) 27-31.03.2012.
8. A. Zmitrowicz, Contact models incorporating effects of wear debris, CMM 2009, *18th International Conference on Computer Methods in Mechanics*, Zielona Góra 18-21.05.2009.
9. A. Zmitrowicz, Descriptions of contact in the presence of wear debris, *80th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM-Jahrestagung)*, Gdańsk 9-13.02.2009.
10. A. Zmitrowicz, Contact stresses – models and methods of computation, *36th Solid Mechanics Conference*, Gdańsk 9-12.09.2008.
11. A. Zmitrowicz, Thermomechanics of wearing out solids, *First Polish Congress of Mechanics*, Warsaw 28-31.08.2007 (in Polish).
12. A. Zmitrowicz, Contact mechanics of wearing out solids, *IUTAM Symposium "Computational Contact Mechanics"*, Hannover (Germany) 5-8.11.2006.
13. A. Zmitrowicz, A modelling of contact problems for wearing out solids, *35th Solid Mechanics Conference*, Kraków 4-8.08.2006.
14. A. Zmitrowicz, Sliding path curvature dependent friction and wear, *4th Contact Mechanics International Symposium*, Hannover/Loccum (Germany) 4-6.07.2005.
15. A. Zmitrowicz, Evolutions of friction anisotropy and heterogeneity, IUTAM, *21th International Congress of Theoretical and Applied Mechanics*, Warsaw 15-21.08.2004.
16. A. Zmitrowicz, Constitutive equations of anisotropic and heterogeneous friction and their applications, invited talk, organized by Prof . G. Szefer and Mechanics of Materials Section of the Mechanics Committee of The Polish Academy of Sciences, IPPT PAN, Warsaw 18.03.2004 (in Polish).
17. A. Zmitrowicz, Solution algorithms of contact problems with wear debris between sliding surfaces, CMM-2003, *15th International Conference on Computer Methods in Mechanics*, Wisła 3-6.06.2003.
18. A. Zmitrowicz, Three-body contact problems and solution algorithms, *34th Solid Mechanics Conference*, Zakopane 2-7.09.2002.

19. A. Zmitrowicz, Wear profiles and wear debris taken into account in variational approaches to contact mechanics, *Fifth World Congress on Computational Mechanics*, Vienna (Austria) 7-12.07.2002.
20. A. Zmitrowicz, Variational formulations for contact problems with wear debris at an interface between sliding surfaces, *3rd Contact Mechanics International Symposium*, Peniche (Portugal) 17-21.06.2001.
21. A. Zmitrowicz, Variational descriptions of wearing out solids and wear debris between sliding surfaces, seminar presentation, *Kolloquium SFB No. 298*, Universität Darmstadt, Darmstadt (Germany) 26.11.2001.
22. A. Zmitrowicz, 300 years of Coulomb friction law – a history of the science of friction, seminar presentation, Mechanik Fakultät, Universität Darmstadt, Darmstadt (Germany) 7.11.2001.
23. A. Zmitrowicz, Constitutive equations for anisotropic and inhomogeneous friction, seminar presentation, Institut für Mechanik III, Universität Darmstadt, Darmstadt (Germany) 20.09.2001.
24. A. Zmitrowicz, Strong and weak formulations of contact problems with various laws of friction, frictional heat and wear, *6th German-Polish Workshop "Dynamical Problems in Mechanical Systems"*, Söllerhaus (Germany) 12-18.09.1999.
25. A. Zmitrowicz, Variational descriptions of contact problems for rubbing and wearing solids, *XIV Polish Conference on Computer Methods in Mechanics*, Rzeszów 26-28.05.1999.
26. A. Zmitrowicz, Variational approach to contact friction and wear problems, *GAMM-Jahrestagung*, Metz (France) 12-16.04.1999.
27. A. Zmitrowicz, Constitutive equations for non-homogeneous and anisotropic friction, *32nd Solid Mechanics Conference*, Zakopane 1-5.09.1998.
28. A. Zmitrowicz, Vibrations of turbine assemblies with stick and slip conditions, *IUTAM Symposium "Unilateral Multibody Dynamics"*, Munich (Germany) 3-7.08.1998.
29. A. Zmitrowicz, Anisotropic friction with sliding path curvature effects: first and higher-order descriptions, *Euromech Colloquium No. 351 "Systems with Coulomb Friction"*, Vadstena (Sweden) 5-7.08.1996.
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