ABSTRACTS

Krzysztof Magnucki Ewa Magnucka-Blandzi
Dynamic Stability of a Three-Layer Beam – Generalization of the Sandwich Structures Theory

The work focuses on the dynamic stability problem of a simply supported three-layer beam subjected to a pulsating axial force. Two analytical models of this beam are developed: one model takes into account the non-linear hypothesis of cross-section deformation, and the other takes into account the standard "broken line" hypothesis. Displacements, strains and stresses for each model are formulated in detail. Based on the Hamilton principle, equations of motion are determined for each of these models. These systems of two differential equations for each model are approximately solved with the consideration of the axial pulsating force, and the fundamental natural frequencies, critical forces and the Mathieu equation are determined. Detailed studies are performed for an exemplary family of beams. The stable and unstable regions are calculated for the three pulsating load cases. The values of fundamental natural frequencies and critical forces of exemplary beams calculated from two models are compared.

Zbigniew Tyfa, Piotr Reorowicz, Damian Obidowski, Krzysztof Jóźwik
Influence of Fluid Rheology on Blood Flow Haemodynamics In Patient-Specific Arterial Networks of Varied Complexity – In-Silico Studies

Results obtained with computational fluid dynamics (CFD) rely on assumptions made during a pre-processing stage, including a mathematical description of a fluid rheology. Up to this date there is no clear answer to several aspects, mainly related to the question of whether and under what conditions blood can be simplified to a Newtonian fluid during CFD analyses. Different research groups present contradictory results, leaving the question unanswered. Therefore, the objective of this research was to perform steady-state and pulsatile blood flow simulations using eight different rheological models in geometries of varying complexity. A qualitative comparison of shear- and viscosity-related parameters showed no meaningful discrepancies, but a quantitative analysis revealed significant differences, especially in the magnitudes of wall shear stress (WSS) and its gradient (WSSG). We suggest that for the large arteries blood should be modelled as a non-Newtonian fluid, whereas for the cerebral vasculature the assumption of blood as a simple Newtonian fluid can be treated as a valid simplification.

Olha Dvirna
The Innovative Post-Weld Finishing Method and Non-Standard Cutting Tool for Carrying out this Method

The most common method of post-weld finishing is grinding with an abrasive tool. This finishing method leads to the occurrence of faults on the treated surface: locations missed or hardened twice, structural notches and stretching residual stress in the surface layer. The faults mentioned lead to the creation and development of ordinary as well as fatigue cracks, seizing or other damage. In addition, grinding is a process that often involves manual labour, which significantly increases the time required for finishing the procedure. Moreover, it is impossible to automate this process. Also, grinding is a process that is damaging for both people and the environment. In contrast to grinding and other processes of post-weld surface finishing, the innovative method, which is the subject of this article, does not have the faults and inconveniences of the previously mentioned techniques. The post-weld surface finishing method by moving of the innovative multi-edge cutting tool along the weld bead is presented in this article. In this method, machining allowance is treated as the weld bead height, which is flush-removed with the base material in one step during one pass of the cutting tool. The adjacent teeth height of changing and increasing according to the direction of feed and the difference in height between the first and last teeth are equal to the weld bead height. The number of cutting teeth necessary to flush-finish the weld bead with the base metal surface depends on the difference in the first and last teeth height and how it is divided. The tooth length is greater than half of the distance between the adjacent cutting teeth, which enables finishing the heterogeneous post-weld surface with many defects and increased hardness. The innovative method is characterised by short machining time of the weld bead and provides an accurate, efficient and economical process.

Leszek Cedro, Krzysztof Wieczorkowski, Adam Szcześniak
An Adaptive PID Control System for the Attitude and Altitude Control of a Quadcopter

In adaptive model-based control systems, determining the appropriate controller gain is a complex and time-consuming task due to noise and external disturbances. Changes in the controller parameters were assumed to be dependent on the quadcopter mass, which was the process variable. A nonlinear model of the plant was used to identify the mass, employing the weighted recursive least squares (WRLS) method for online identification. The identification and control processes involved filtration using differential filters, which provided appropriate derivatives of signals. Proportional integral derivative (PID) controller tuning was performed using the Gauss–Newton optimisation procedure on the plant. Differential filters played a crucial role in all the developed control systems by significantly reducing measurement noise. The results showed that the performance of classical PID controllers can be improved by using differential filters and gain scheduling. The control and identification algorithms were implemented in an National Instruments (NI) myRIO-1900 controller. The nonlinear model of the plant was built based on Newton's equations.

Katarzyna Makowska, Tadeusz Szymczak, Zbigniew L. Kowalewski
Fatigue Behaviour of Medium Carbon Steel Assessed by the Barkhausen Noise Method

In this paper, an attempt to estimate the stage of the fatigue process using the Barkhausen noise method is studied. First, microstructural and static tensile tests were carried out and, subsequently, fatigue tests up to failure were conducted. After determination of the material behaviour in the assumed static and dynamic conditions, the interrupted fatigue tests were performed. Each specimen was stressed up to a different number of cycles corresponding to 10%, 30%, 50%, 70% and 90% of fatigue lifetime for the loading conditions considered. In the next step of the experimental programme, the specimens were subjected to the Barkhausen magnetic noise measurements. Various magnetic parameters coming from the rms Barkhausen noise envelopes were determined. The linear relationship between the full-width at half-maximum (FWHM) of the Barkhausen noise envelope and the number of loading cycles to fracture was found. Specimens loaded up to a certain number of cycles were also subjected to a tensile test to assess an influence of fatigue on the fracture features.

Muhammad Amir, Asifa Ashraf, Jamil Abbas Haider
The Variational Iteration Method for a Pendulum with a Combined Translational and Rotational System

The dynamic analysis of complex mechanical systems often requires the application of advanced mathematical techniques. In this study, we present a variation iteration-based solution for a pendulum system coupled with a rolling wheel, forming a combined translational and rotational system. Furthermore, the Lagrange multiplier is calculated using the Elzaki transform. The system under investigation consists of a pendulum attached to a wheel that rolls without slipping on a horizontal surface. The coupled motion of the pendulum and the rolling wheel creates a complex system with both translational and rotational degrees of freedom. To solve the governing equations of motion, we employ the variation iteration method, a powerful numerical technique that combines the advantages of both variational principles and iteration schemes. The Lagrange multiplier plays a crucial role in incorporating the constraints of the system into the equations of motion. In this study, we determine the Lagrange multiplier using the Elzaki transform, which provides an effective means to calculate Lagrange multipliers for constrained mechanical systems. The proposed solution technique is applied to analyse the dynamics of a pendulum with a rolling wheel system. The effects of various system parameters, such as the pendulum length, wheel radius and initial conditions, are investigated to understand their influence on the system dynamics. The results demonstrate the effectiveness of the variation iteration method combined with the Elzaki transform in capturing the complex behaviour of a combined translational and rotational system. The proposed approach serves as a valuable tool for analysing and understanding the dynamics of similar mechanical systems encountered in various engineering applications.

Thomas Koch, Dominik Wenzel, Ralf Gläbe
Machining of TiAl6V4 using Lubricants Containing Renewable Microalgae-Born Performance Additives

Titanium and its alloys represent a special class of materials. A density of 4.81 g/cm³, a tensile strength of over 1,200 MPa, a fa-tigue strength greater than that of steel, a low modulus of elasticity and its self-passivating, inert surface make titanium an ideal material for lightweight structures in aerospace, marine applications, the chemical industry and medical implants. Although titanium is inert in its oxidised state, its nascent surface created in machining reacts with almost everything in its environment, including the tool. Moreover, its poor thermal conductivity results in high thermal stress on the tools. Overall, these properties lead to high wear rates and result in the requirement for finding a particularised solution for processes such as milling that involve the need to overcome such challenges. Such processes therefore require lubricants with well-selected performance additives. However, most of these performance additives are based on mineral oil and thus come from a non-renewable resource. In the presented work, environmental-friendly alternatives to conventional mineral oil-based performance additives were investigated. Due to the working mechanisms of performance additives in machining, this work focusses on sulphur- and phosphorus-containing polysaccharides and proteins from microalgae. It has been successfully shown that lubricants using extracts from microalgae as performance additives can be used for high-speed milling (HSC) of TiAl6V4. The investigated extracts were able to reach the performance level of conventional additives in terms of tool lifetime and wear. The results obtained show that appropriate alternatives to mineral oil-based additives exist from renewable raw-material sources.

Tadeusz Bohdal, Małgorzata Sikora, Karolina Formela
Thermal and Visualisation Study of the HFE7100 Refrigerant Condensation Process

Technological advances are contributing to the search for highly efficient energy designs, and increasing interest in compact heat exchangers. Indeed, small channel diameters determine large heat transfer coefficients and condition a significant heat transfer area about the overall volume of the heat exchanger, as well as a smaller amount of refrigerant flowing in the system. Nevertheless, the operating stability and energy efficiency of compact heat exchangers are influenced by two-phase flow structures, which depend on thermal flow parameters. Knowledge of the structures formed during the condensation process is therefore essential for optimising the operation of refrigeration and air-conditioning equipment. This article presents the results from experimental studies of the HFE7100 refrigerant, from the hydrofluorocarbon group, condensation process in mini-channels with hydraulic diameters d_h = 2.0 mm, 1.2 mm, 0.8 mm and 0.5 mm. Thermal flow characteristics were determined, and the forming structures of two-phase flow were recorded. The results of visualisation were subjected to morphological image analysis, based on a special algorithm written in MATLAB software. The algorithm makes it possible to determine the void fraction, which is necessary for calculating the vapour quality, as well as the area of vapour bubbles and their number, directionality and length along the x- and y-axes.

Noura Rezika Hatem Bellahsene
Fuzzy Based Supervision Approach in the Event of Rotational Speed Inversion in an Induction Motor

This article aims to implement the fuzzy control for an asynchronous motor after a general representation of the vector control. We develop MAMDANI type fuzzy algorithm for MAS speed regulation; it's one purpose is to cancel static error, decrease overshoot, decrease response time, and rise time to obtain an adequate response of the process and regulation and to have a precise, fast, stable and robust system. This paper investigates the design of a fuzzy-based approach for monitoring the inversion of the rotational speed of an induction motor. We will indeed present a robust vector control technique ex-tended to blur in the event of a fault. Direct torque control is known to produce fast and robust response in the AC drive system. However, in a steady state, a rapid and unexpected change in speed can occur which could be dangerous. The performance of the conventional PID controller can be improved by implementing fuzzy logic techniques. The first step is the modelling of the whole system, including the capacitors, the induction generator and the loads. The model is obtained using the Park transformation. The results are thus compared with those of the standard PID control. This approach is applied to a three-phase asynchronous motor (LS90Lz). The presented study improves the transient response time and the precision of the servo system. An inversion of the reference speed of rotation is considered, and the results are very convincing.

Ewa Piotrowska, Rafał Melnik
Analysis of Fractional Electrical Circuit Containing Two RC Ladder Elements of Different Fractional Orders

The study addresses the topic of different fractional orders in the context of simulation as well as experiments using real electrical elements of fractional-order circuit. In studying the two solutions of the resistance-capacitance (RC) ladder circuit of appropriate pa-rameters, different fractional orders of the electrical circuit are considered. Two fractional-order (non-integer) elements were designed based on the Continued Fraction Expansion (CFE) approximation method. The CFE method itself was modified to allow free choice of centre pulsation. It was also proposed that when making individual ladder circuits, in the absence of elements with the parameters specified by the program, they should be obtained by connecting commercially available elements in series or parallel. Finally, the theoretical analysis of such a circuit is presented using state-space method and verified experimentally.

Aziz Ur Rehman, Fahd Jarad, Muhammad Bilal Riaz
A Fractional Study of MHD Casson Fluid Motion with Thermal Radiative Flux and Heat Injection/Suction Mechanism under Ramped Wall Condition: Application of Rabotnov Exponential Kernel

The primary objective of this research is to extend the concept of fractionalized Casson fluid flow. In this study, a comprehensive analysis of magnetohydrodynamic (MHD) natural convective flow of Casson fluid is conducted, focusing on obtaining analytical solutions using the non-integer-order derivative known as the Yang–Abdel-Aty–Cattani (YAC) operator. The YAC operator utilized in this research possesses a more generalized exponential kernel. The fluid flow is examined in the vicinity of an infinitely vertical plate with a characteristic velocity denoted as u_0. The mathematical modelling of the problem incorporates partial differential equations, incorporating Newtonian heating and ramped conditions. To facilitate the analysis, a suitable set of variables is introduced to transform the governing equations into a dimensionless form. The Laplace transform (LT) is then applied to the fractional system of equations, and the obtained results are presented in series form and also expressed in terms of special functions. The study further investigates the influence of relevant parameters, such as α, β, P_r, Q, G_r, M, N_r and K, on the fluid flow to reveal interesting findings. A comparison of different approaches reveals that the YAC method yields superior results compared to existing operators found in the literature. Graphs are generated to illustrate the outcomes effectively. Additionally, the research explores the limiting cases of the Casson and viscous fluid models to derive the classical form from the YAC ractionalized Casson fluid model.

Ewa Kozak-Jagieła, Monika Rerak, Wiesław Zima, Artur Cebula, Sławomir Grądziel, Giorgia Mondino, Richard Blom, Lars O. Nord, Vidar T. Skjervold
The CO2 Capture System with a Swing Temperature Moving Bed

The reduction in CO2 emissions is now a very popular topic. According to the International Energy Agency, CO2 emitted in 2021

was 6% more than that emitted in 2020. Carbon capture and storage (CCS) is gaining popularity as a possible solution to climate change. Experts estimate that industry and power plants will be responsible for 19% of total CO2 emissions by 2050. This paper presents the design of a semi-industrial-scale system for CO2 capture based on the moving bed temperature swing adsorption technology. According to the results of laboratory tests conducted by the SINTEF industry, this technology demonstrates high capture efficiency (>85%). The CO2 capture medium involved in adsorption is activated carbon passing through individual sections (cooling, heating, adsorption), where CO2 is bonded and then released. The heat and mass transfer processes are realised on the developed stand. The heat exchangers use steam and water as the heating/cooling medium. The paper reviews the existing solutions and describes the developed in-house design of heat exchangers that will ensure heat transfer conditions being a trade-off between economic and efficiency-related issues of the CO2 capture process. The designed test stand will be installed in a Polish power plant and is expected to meet the method energy intensity target, set at ≤ 2.7 MJ/kg CO2, with a capture efficiency exceeding 85%. The aim of the work was to develop and solve technical problems that would lead to the construction of a CO2 capture station with parameters mentioned above. This stand uses an innovative method where CO2 is captured by contacting the fluid (gases) with solid particles. The heat exchange associated with the heating and cooling of the adsorbent had to be solved. For this purpose, heat exchangers were designed with high thermal efficiency and to prevent the formation of mounds.

Mariusz Leus, Paweł Gutowski
Friction Force Reduction Efficiency in Sliding Motion under Tangential Vibrations of Elastic Support

The efficiency of reducing the friction force in sliding motion under the influence of forced vibrations of an elastic substrate significantly depends on the direction of these vibrations in relation to the sliding direction. This article presents a comparison of computational models developed by the authors to estimate the friction force in sliding motion under longitudinal and transverse tangential vibrations of the substrate. Fundamental differences between these models are discussed, and the results of comparative analyses of the impact of tangential vibrations on the friction force depending on their direction are presented. In the developed models describing the friction force, dynamic friction models of Dahl and Dupont and the so-called LuGre model were utilised. The analyses were performed as a function of the sliding velocity and two basic parameters of vibration, which are frequency f and amplitude u0. It has been shown that under longitudinal vibrations, the key parameter, which determines the occurrence of friction force reduction at a given driving velocity vd, is the amplitude va of vibration velocity. However, the level of this reduction cannot be determined unequivocally based on the value of this parameter alone since the identical value va can be obtained at different magnitudes of the frequency and amplitude of vibrations, and the reduction level is a nonlinear function of these parameters. The results of simulation analyses were verified experimentally.

Mourad Ouyadri, Mohamed Laabissi, Mohammed Elarbi Achhab
Positive State Controllability of Discrete Linear Time-Invariant Systems

Positive state controllability is the controllability of systems where the state is positive and the input remains in $\mathbb{R}^n$. Under some conditions, we established a relation between the reachability map of systems with only the positive state and the reachability map of a related positive system where the state and input are both positive. Using this connection, necessary and sufficient conditions are obtained for the positive state reachability of discrete linear time-invariant (LTI) systems, and then we deduced the positive state controllability. These conditions are evaluated over some numerical examples that support the theoretical results.

Tadeusz Kaczorek,Jerzy Klamka, Andrzej Dzieliński
Controllability and Observability of the Descriptor Linear Systems Reduced to the Standard Ones by Feedbacks

In this paper, a new method for the reduction of the descriptor linear systems to standards ones is presented and verified. The method uses a state and/or state derivative feedback of output and output derivative feedback in order to transform the descriptor system into a standard one. The controllability and observability properties of the original descriptor as well as transformed standard systems are proved. Simple numerical examples illustrate the theorems introduced.

Muhammad Amir, Jamil Abbas Haider, Asifa Ashraf
The Homotopy Perturbation Method for Electrically Actuated Microbeams In Mems Systems Subjected to Van Der Waals Force and Multiwalled Carbon Nanotubes

This paper presents a summary of a study that uses the Aboodh transformation and homotopy perturbation approach to analyze the behavior of electrically actuated microbeams in microelectromechanical systems that incorporate multiwalled carbon nanotubes and are subjected to the van der Waals force. All of the equations were transformed into linear form using the HPM approach. Electrically operated microbeams, a popular structure in MEMS, are the subject of this work. Because of their interaction with a nearby surface, these microbeams are sensitive to a variety of forces, such as the van der Waals force and body forces.

MWCNTs are also incorporated into the MEMSs in this study because of their special mechanical, thermal, and electrical characteristics. The suggested method uses the HPM to model how electrically activated microbeams behave when MWCNTs and the van der Waals force are present. The nonlinear equations controlling the dynamics of the system can be roughly solved thanks to the HPM. The HPM offers a precise and effective way to analyze the microbeam's reaction to these outside stimuli by converting the nonlinear equations into linear forms. The study's findings shed important light on how electrically activated microbeams behave in MEMSs. A more thorough examination of the system's performance is made possible with the addition of MWCNTs and the van der Waals force. With its ability to approximate solutions and characterize system behavior, the HPM is a potent instrument that improves comprehension of the physics at play and facilitates the design and optimization of MEMS devices. The aforementioned method's accuracy is verified by comparing it with published data that directly aligns with Anjum et al.'s findings. We have faith in this method's accuracy and its current application.

Nidhish Kumar Mishra
Computer Simulation of Heat and Mass Transfer Effects on Nanofluid Flow of Blood Through an Inclined Stenosed Artery with Hall Effect

The present study deals with the analysis of heat and mass transfer for nanofluid flow of blood through an inclined stenosed artery under the influence of the Hall effect. The effects of hematocrit-dependent viscosity, Joule heating, chemical reaction and viscous dissipation are taken into account in the governing equations of the physical model. Non-dimensional differential equations are solved using the finite difference method, by taking into account the no-slip boundary condition. The effects of different thermophysical parameters on the velocity, temperature, concentration, shear stress coefficient and Nusselt and Sherwood numbers of nano-biofluids are exhaustively discussed and analysed through graphs. With an increase in stenosis height, shear stress, the Nusselt number and the Sherwood number are computed, and the impacts of each are examined for different physical parameters. To better understand the numerous phenomena that arise in the artery when nanofluid is present, the data are displayed graphically and physically described. It is observed that as the Hartman number and Hall parameter increase, the velocity drops. This is as a result of the Lorentz force that the applied magnetic field has generated. Blood flow in the arteries is resisted by the Lorentz force. This study advances the knowledge of stenosis and other defects' non-surgical treatment options and helps reduce post-operative consequences. Moreover, ongoing research holds promise in the biomedical field, specifically in magnetic resonance angiography (MRA), an imaging method for artery examination and anomaly detection.

Tarig M. Elzaki, Mourad Chamekh, Shams A. Ahmed
Modified Integral Transform for Solving Benney-Luke and Singular Pseudo-Hyperbolic Equations

In this article, we propose a technique based on modified double integral transforms used to solve certain equations of materials science, namely Benney–Luke (BL) and singular pseudo-hyperbolic (SP-H) equations. We have established some analytical results. This method can provide accurate one-step solutions, although the equations used may exhibit a singularity in the initial conditions. Some numerical examples have been discussed for illustration and to show the effectiveness of the technique for certain types of equations. We have developed an exact solution in just one step, whereas other approaches require several stages to succeed in a particular solution, making the proposed strategy particularly successful and straightforward to apply to various varieties of the B–L and SP-H equations.

Yousef Al-Mutayeb, Moayed Almobaied, Mohamed Ouda
Real-time Simulation and Experimental Implementation of Luenburger Observer-Based Speed Sensor Fault Detection of BLDC Motors

Modern control systems' dependability, safety and efficiency have all been improved by studying fault-tolerant control systems (FTCS). FTCS techniques can typically be active or passive controls. The fault detection and diagnosis (FDD) method is used in this study's active control branch to identify probable faults that could develop in the speed Hall sensors of brushless DC motors (BLDC). FDD methodologies can be categorised into two types, depending on the available data and the process involved: model-based methods and data-based methods. The proposed approach in this study explores the implementation of the Luenberger observer methodology as part of the model-based approach. The chosen methodology was practically implemented and subjected to experimental evaluation. The proposed observer relies on the residual signal, which displays the difference between the plant's observed and estimated speed signals and serves as a failure alert for the entire system. Given the increasing demand for BLDC motors in various industrial control applications, including medical fields, automation and robotics, this particular motor was selected as a benchmark to thoroughly evaluate and validate the proposed method. The primary contribution of this paper lies in the real-time application of model-based sensor fault detection methods to BLDC motors. The efficiency of the suggested method is showcased through extensive MATLAB simulations, where the obtained results confirm the successful detection of faults with a high level of responsiveness. As a result, the project was successfully implemented in real-time, and the experimental results exhibited a close correlation with the simulated outcomes. This consistency between simulation and practical implementation validates the accuracy and reliability of the proposed methodology for detecting faults in the BLDC motor speed sensor. The results underscore the heightened reliability and safety attained by promptly and accurately detecting sensor faults during the operation of the motor.

Łukasz Jastrzębski, Bogdan Sapiński
Examination of a Magnetorheological Damper Control System with Vibration Energy Harvesting

The study deals with the experimental examination of a magnetorheological (MR) damper control system with vibration energy harvesting using a specially engineered electronic unit (EU). Unlike a typical MR damper control system, which requires an external energy source, the developed system is powered exclusively by energy extracted from a vibrating structure (mechanical system with one-degree-of freedom) and processed through the EU. The work describes the structure and functions of the EU, presents the test rig and the control algorithm implementation, and discusses the test results of the control system under harmonic kinematic excitations of low frequency range.