ABSTRACTS

Zbyszko Klockiewicz, Grzegorz Ślaski
Comparison of Vehicle Suspension Dynamic Responses for Simplified and Advanced Adjustable Damper Models with Friction, Hysteresis and Actuation Delay for Different Comfort-Oriented Control Strategies

Throughout the years, many control strategies for adjustable dampers have been proposed, designed to boost the performance characteristics of a vehicle. Comfort control strategies such as Skyhook (SH), acceleration-driven damping or power-driven damping have been tested many times using simulation models of vehicles. Those tests, however, were carried out using simplified damper models – linear or simple bilinear with symmetric characteristics. This article presents the results of examination of the influence of using more complex damper models, with friction, hysteresis and time delay of state switching implemented, on the chosen dynamic responses of a suspension system for excitations in the typical exploitation frequency range. The results of the test are compared with those found in the literature and with the results of simulations performed with a simplified version of the advanced model used. The main conclusion is that friction and hysteresis add extra force to the already existing damping force, acting like a damping increase for all analysed control strategies. The actuation delays limit the effectiveness in a sense of comfort increasing to only some frequencies. The research shows the importance of including the proposed modules in testing for both adjustable and passive dampers.

Piotr Odyjas, Jędrzej Więckowski, Damian Pietrusiak, Przemysław Moczko
Challenges in the Design of New Centrifugal Fan with Variable Impeller Geometry

This article presents a description of design work for newly created centrifugal fans. This was done based on the example of an innovative solution that uses a change in impeller geometry. In the described solution, this is achieved by shortening and lengthening the impeller blades. The development of a technical solution with such properties requires a change of approach in the design process compared with classic solutions. Therefore, the following text describes this process from the concept stage to demonstrator tests. The principle of operation of such a solution is presented and the assumptions made based on analytical calculations are also described. The text also shows a 3D model of the centrifugal fan with variable impeller geometry, made with the help of computer aided design (CAD) tools. In the further part, numerical calculations were made on its basis. The finite element method (FEM) calculation made it possible to verify the structural strength of the project and its modal properties as well as to verify flow parameters, thanks to the use of computational fluid dynamics (CFD) calculations. The next step describes the procedure for testing centrifugal fans with variable rotor geometry, which is different from that of fans without this feature. The next part presents the results of research from the tests carried out.

Bartosz Wieczorek, Łukasz Warguła, Mateusz Kukla
Influence of a Hybrid Manual–Electric Wheelchair Propulsion System on the User's Muscular Effort

Self-propelled wheelchairs favour the rehabilitation process, forcing the user to be physically active. Unfortunately, in most cases, the manual propulsion is not adapted to the individual needs and physical capabilities of the user. This paper presents the results of operational tests of a wheelchair equipped with a hybrid propulsion system in which the muscle strength generated by the user is assisted by two independent electric motors. The research aimed to investigate the influence of the applied control algorithm and the assistance factor (W) on the value of the muscular effort (MA) while propelling the wheelchair with the use of push rims. A modified ARmedical AR-405 wheelchair equipped with two MagicPie 5 electric motors built into the wheelchair's hubs with a power of 500 W was used in this research. The tests were carried out on a wheelchair test bench simulating the moment of resistance within the range of 8–11 Nm. Surface electromyography was employed for the measurement of MA, specifically, a four-channel Noraxon Mini DTS apparatus. The research was carried out on five patients from the group of C50 anthropometric dimensions. The effort was measured for four muscles: deltoid–anterior part, deltoid–posteriori part, and triceps brachii and extensor carpi radialis longus. The effectiveness of the hybrid propulsion system was observed based on the extensor carpi radialis longus muscle. In this case, for the standard wheelchair, the MA ranged from 93% to 123%. In contrast, for a wheelchair equipped with the hybrid propulsion system, at W = 70%, the MA was within the range of 43%–75%.

Mária Michalková, Ivana Pobočíková,
Time Series Analysis of Fossil Fuels Consumption in Slovakia by ARIMA Model

According to the Green Deal, the carbon neutrality of the European Union (EU) should be reached partly by the transition from fossil fuels to alternative renewable sources. However, fossil fuels still play an essential role in energy production, and are widely used in the world with no alternative to be completely replaced with, so far. In recent years, we have observed the rapidly growing prices of commodities such as oil or gas. The analysis of past fossil fuels consumption might contribute

significantly to the responsible formulation of the energy policy of each country, reflected in policies of related organisations and the industrial sector. Over the years, a number of papers have been published on modelling production and consumption of fossil and renewable energy sources on the level of national economics, industrial sectors and households, exploiting and comparing a variety of approaches. In this paper, we model the consumption of fossil fuels (gas and coal) in Slovakia based on the annual data during the years 1965–2020. To our knowledge, no such model, which analyses historical data and provides forecasts for future consumption of gas and coal, respectively, in Slovakia, is currently available in the literature. For building the model, we have used the Box–Jenkins methodology. Because of the presence of trend in the data, we have considered the autoregressive integrated moving average (ARIMA (p,d,q)) model. By fitting models with various combinations of parameters p, d, q, the best fitting model has been chosen based on the value of Akaike's information criterion. According to this, the model for coal consumption is ARIMA(0, 2, 1) and for gas consumption it is ARIMA(2, 2, 2).

Pavol Šťastniak, Michal Rakár, Jakub Tížek
Design of a Height-Adjustable Boarding System for a New Double-Deck Railway Vehicle

This paper deals with a solution for faster and safer boarding and leaving of passengers at railway station platforms from 150 mm to 550 mm higher than the head of the rail. This conception is based on the requirements of railway infrastructure administrators, transporters and also manufacturers of passenger rolling stock. This device is designed for the new double-deck railway vehicle for suburban and regional transport, which fulfils legislative and normative requirements that are specified for the selected area of vehicle construction and operational features. Selected parts of the construction were verified through a series of simulation analyses. This article also includes a study that deals with optimization of the boarding area considering designed changes in the construction of the floor and a draft for modification of the vertical clearance of the boarding entrance area in a rough construction of the vehicle.

Jacek Jackiewicz
A Flywheel-Based Regenerative Braking System for Railway Vehicles

Regenerative braking is a technique that employs electric motors to convert the dynamic mechanical energy from the motor's spinning rotor and any attached loads into electricity. However, such a type of regenerative braking can only slow but not stop the vehicle because there is too little energy to excite the motor acting as a generator at low speeds. Therefore, this paper presents a unique flywheel-based regenerative braking system for railway vehicles. This system is supposed to meet high safety and comfort expectations in all operating conditions. The braking action control of this system should allow braking of empty or loaded vehicles according to load, the anti-blockage braking action of wheels and prevent wheel-slide during braking or wheel slip during acceleration. The new regenerative braking system under development, like any kinetic energy recovery system, requires the application of continuously variable transmission. The essence of the new solution is to design and build this type of variable transmission using only one planetary gear controlled through the powertrain control module for an electric motor cooperating concurrently. This paper describes complete modelling and simulation realisation on a closed-loop servomotor drive, which cooperates with the variable transmission of the regenerative braking system based on the Scilab/Xcos environment.

Ján Dižo, Miroslav Blatnický, Paweł Droździel, Rafał Melnik, Jacek Caban, Adam Kafrik
Investigation of Driving Stability of a Vehicle-Trailer Combination Depending on the Load's Position within the Trailer

Passenger cars are a means of transportation used widely for various purposes. The category that a vehicle belongs to is largely responsible for determining its size and storage capacity. There are situations when the capacity of a passenger vehicle is not sufficient. On the one hand, this insufficient capacity is related to a paucity in the space needed for stowing luggage. It is possible to mount a rooftop cargo carrier or a roof basket on the roof of a vehicle. If a vehicle is equipped with a towbar, a towbar cargo carrier can be used for improving its space capacity. These accessories, however, offer limited additional space, and the maximal load is determined by the maximal payload of the concerned vehicle. If, on the other hand, there is a requirement for transporting a load with a mass or dimensions that are greater than what could be supported using these accessories, then, provided the vehicle is equipped with a towbar, a trailer represents an elegant solution for such demanding requirements. A standard flat trailer allows the transportation of goods of various characters, such as goods on pallets, bulk material, etc. However, the towing of a trailer changes the distribution of the loads, together with changes of loads of individual axes of the vehicle–trailer axles. The distribution of the loads is one of the key factors affecting the driving properties of a vehicle–trailer combination in terms of driving stability, which is mainly a function of the distribution of the load on the trailer. This research introduces a study into how the distribution of the load on a trailer influences the driving stability of a vehicle–trailer combination. The research activities are based on simulation computations performed in a commercial multibody software. While the results presented in the article are reached for a particular vehicle–trailer combination as well as for a particular set of driving conditions, the applicability of the findings can also be extended more generally to the impact that the load distributions corresponding to various vehicle–trailer combinations have on the related parameters and other driving properties.

Dariusz Kurpisz, Maciej Obst, Tadeusz Szymczak, Radosław Wilde
Analytical Approach for Vehicle Body Structures Behaviour under Crash at Aspects of Overloading and Crumple Zone Length

Road safety problem is still topical, especially since the number of vehicles and the volume of traffic are increasing. It is possible to increase the safety of road users through systemic changes in many areas related to transport. The deformation of the vehicle body during an accident has an impact on the loads acting on the passengers. Vehicle body deformation depends on complex parameters, and knowledge of these parameters is essential for designing crumple zones and the accident reconstruction process. Knowledge of the mechanical parameters of the vehicle structure during deformation is also a reference to passenger injury indicators assessment. This paper reports results from the analytical approach for determining the protection level of personal vehicles. The proposed conception is based on the results from the static stiffness characteristic of the Ford Taurus, which gives the possibility of phenomenological and simple body crumple analytical description at a speed equal to 10 km/h, 40 km/h, 56 km/h and 60 km/h, which is an original part of the work. The approach enables us to describe the vehicle crash by focusing on variations of deformation in time, stiffness, vehicle collision time (duration), deceleration and dynamic crash force. Basing on the body stiffness data of the personal vehicle, the length of the deformation zone in the front of the car and the maximum values of force at the crash for a speed of 60 km/h are presented. Results obtained by the authors show that is possible to estimate the overloading level during the crash time of a vehicle based on the stiffness characteristic of the car body. The proposed methodology can be developed and the advantage of the presented procedure is an uncomplicated useful tool for solving complex problems of a vehicle crash.

Paweł Bałon, Bartłomiej Kiełbasa, Łukasz Kowalski, Robert Smusz
Thermal Performance of the Thermal Storage Energy With Phase Change Material

Values of energy supply and demand vary within the same timeframe and are not equal. Consequently, to minimise the amount of energy wasted, there is a need to use various types of energy storing systems. Recently, one can observe a trend in which phase change materials (PCM) have gained popularity as materials that can store an excess of heat energy. In this research, the authors analysed paraffin wax (cheese wax)'s capability as a PCM energy storing material for a low temperature energy-storage device. Due to the relatively low thermal conductivity of wax, the authors also analysed open-cell ceramic Al2O3/SiC composite foams' (in which the PCM was dispersed) influence on heat exchange process. Thermal analysis on paraffin wax was performed, determining its specific heat in liquid and solid state, latent heat (LH) of melting, melting temperature and thermal conductivity. Thermal tests were also performed on thermal energy container (with built-in PCM and ceramic foams) for transient heat transfer. Heat transfer coefficient and value of accumulated energy amount were determined.

Piotr Rybak, Zdzisław Hryciów, Bogusław Michałowski, Andrzej Wiśniewski
Assessment of the Impact of Wear and Tear of Rubber Elements in Tracked Mechanism on the Dynamic Loads of High-Speed Tracked Vehicles

The operation of high-speed tracked vehicles takes place in difficult terrain conditions. Hence, to obtain a high operational relia-bility, the design or modernisation process must be precise and should consider even the slightest details. The article presents issues related to the problem of formulating vehicle models using partial models of flexible elements used in tracked mechanisms. Changes occurring in the shape and properties of elements such as track pads and roadwheel bandages as a consequence of operating conditions are presented. These changes are reflected in the presented elastic–damping characteristics of components of the crawler mechanism. Numerical studies have shown that deterioration of chassis suspension components after a significant mileage may increase dynamic loads (forces) acting on the running gear. Increased forces in the running gear naturally result in increased stresses in the road surface on which the vehicle is travelling, which can pose a danger (or excessive wear and tear) to road infrastructure components such as culverts, bridges and viaducts. In the literature, model tests of objects are carried out on models that represent new vehicles, and the characteristics of the adopted elements correspond to elements not affected by the process and operating conditions. Its influence should not be ignored in the design, testing and running of a special vehicle. The tracked mechanism, as running gear, is designed for special high-speed vehicles for off-road and off-road driving. Its design ensures high off-road traversability. The dynamic loads originating from off-road driving are superimposed on those generated by the engine, drive train and interaction of the tracks with the roadwheels, sprocket, idler and supporting tracks return rollers.

Robert Baran, Krzysztof Michalczyk, Mariusz Warzecha
Experimental Analysis of Transverse Stiffness Distribution of Helical Compression Springs

This paper presents the results of an experimental analysis of the distribution of transverse stiffness of cylindrical compression helical springs with selected values of geometric parameters. The influence of the number of active coils and the design of the end coils on the transverse stiffness distribution was investigated. Experimental tests were carried out for 18 sets of spring samples that differed in the number of active coils, end-coil design and spring index, and three measurements were taken per sample, at two values of static axial deflection. The transverse stiffnesses in the radial directions were tested at every 30° angle. A total of 1,296 measurements were taken, from which the transverse stiffness distributions were determined. It was shown

that depending on the direction of deflection, the differences between the highest and lowest value of transverse stiffness of a given spring can exceed 25%. The experimental results were compared with the results of the formulas for transverse stiffness available in the literature. It was shown that in the case of springs with a small number of active coils, discrepancies between the average transverse stiffness of a given spring and the transverse stiffness calculated based on literature relations can reach several tens of percent. Analysis of the results of the tests carried out allowed conclusions to be drawn, making it possible to estimate the suitability of a given computational model for determining the transverse stiffness of a spring with given geometrical parameters.

Yuriy Pyr'yev, Andrzej Penkul, Leszek Cybula
Research of Dynamic Processes in an Anvil During a Collision with a Sample

The paper concerns modelling the dynamics of the contact system of the tested sample with an elastic half-space (anvil) during their collision. The original elements in the paper include the proposed general approach to solving the problem of contact dynamics. The presented approach consists in determining the force of impact on the sample during the collision and the joint solution of the problem for the tested sample and the problem for an elastic semi-space under the conditions of the assumptions of Hertz's theory. The resulting interaction forces allow the determination of displacements and stresses.

Bouchmel Mliki, Rached Miri, Ridha Djebali, Mohamed A. Abbassi
CuO–Water MHD Mixed Convection Analysis and Entropy Generation Minimization in Double-Lid–Driven U-Shaped Enclosure with Discrete Heating

The present study explores magnetic nanoliquid mixed convection in a double lid–driven U-shaped enclosure with discrete heating using the lattice Boltzmann method (LBM) numerical method. The nanoliquid thermal conductivity and viscosity are calculated using the Maxwell and Brinkman models respectively. Nanoliquid magnetohydrodynamics (MHD) and mixed convection are analyzed and entropy generation minimisation has been studied. The presented results for isotherms, stream isolines and entropy generation describe the interaction between the various physical phenomena inherent to the problem including the buoyancy, magnetic and shear forces. The operating parameters' ranges are: Reynolds number $(\mathrm{Re}: 1-100)$, Hartman number $(\mathrm{Ha}: 0-80)$, magnetic field inclination (γ: $0°-90°$), nanoparticles volume fraction (ϕ: $0-0.04$) and inclination angle (α: $0°-90°$). It was found that the $\mathrm{N_{um}}$ and the total entropy generation augment by increasing Re, ϕ: and γ. conversely, an opposite effect was obtained by increasing Ha and α. The optimum magnetic field and cavity inclination angles to maximum heat transfer are $\gamma = 90°$ and $\alpha = 0$.

Andrew Omame, Fiazud Din Zaman
Solution of the Modified Time Fractional Coupled Burgers Equations Using the Laplace Adomian Decomposition Method

In this work, a coupled system of time-fractional modified Burgers' equations is considered. Three different fractional operators: Caputo, Caputo-Fabrizio and Atangana-Baleanu operators are implemented for the equations. Also, two different scenarios are examined for each fractional operator: when the initial conditions are $\mathrm{u(x,y,0)} = \sin(\mathrm{xy})$, $\mathrm{v(x,y,0)} = \sin(\mathrm{xy})$, and when they are $\mathrm{u(x,y,0)} = \mathrm{e^{\{-kxy\}}}$, $\mathrm{v(x,y,0)} = \mathrm{e^{\{-kxy\}}}$, where k, α are some positive constants. With the aid of computable Adomian polynomials, the solutions are obtained using Laplace Adomian decomposition method (LADM). The method does not need linearization, weak nonlinearity assumptions or perturbation theory. Simulations are also presented to support theoretical results, and the behaviour of the solutions under the three different fractional operators compared.

Patryk Różyło
Failure Analysis of Beam Composite Elements Subjected to Three-Point Bending using Advanced Numerical Damage Models

This paper deals with the experimental and numerical analysis of three-point bending phenomenon on beam composite profiles. Flat rectangular test specimens made of carbon–epoxy composite, characterised by symmetric [0/90/0/90]s laminate ply lay-up, were used in this study. Experimental testing was carried out with a COMETECH universal testing machine, using special three-point bending heads. In addition, macroscopic evaluation was performed experimentally using a KEYENCE Digital Microscope with a mobile head recording real-time images. Parallel to the experimental studies, numerical simulations were performed using the finite element method in ABAQUS software. The application of the above-mentioned interdisciplinary research techniques allowed for a thorough analysis of the phenomenon of failure of the composite material subjected to bending. The obtained research results provided a better understanding of the failure mechanism of the composite material.