Abstracts of Papers in English

DESIGN OF CONTROLLER AND INTELLIGENT ADAPTIVE NEURAL IDENTIFIER FOR INNOVATIVE KNEE REHABILITATION DEVICES

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Abstract

Continuous passive motion devices commonly referred to as "CPM" devices are used to maintain and restore joint range of motions. However, this device has been used for many years in joint rehabilitation. It is used especially for the knee, but new research has underestimated the clinical value of this device, which is also available in Iran at a high price and has recommended the development of its capabilities. Therefore, an innovative device with extensive capabilities has been designed to rehabilitate the knee, for which a control system is presented in this article. This system is a combination of CPM device as light as possible and a stationary bike. At the beginning of the treatment cycle, the patient regains a range of motions for his knee with the CPM device and then, regains his muscular strength and balance with the help of a stationary bike (which can maintain a speed of 35 rpm). Using a driving force to create both user modes to reduce production costs and increase economic feasibility is one of the design principles of this system and one of its innovations. On the other hand, the device is designed to be usable for a wide range of patients and its structure can change dimensions in a range. Therefore, the most reasonable way to control this system is to use an adaptive control system. Due to the interaction of the system with humans, PID structure has been used to ensure the stability of the system. One of the most important results presented is the design of an adaptive intelligent identifier and controller for this system. The purpose of designing the intelligent identifier is to cre-

ate an approximate model for estimating the system's online operating point, which is provided to the adaptive intelligent PID controller to update its coefficients depending on the status of the controlled plant.

Key Words: Rehabilitation, Knee, CPM, joint, identifier.

ITERATIVE LEARNING CONTROL TO ENHANCE ACCURACY OF REPETITIVE MANEUVERS FOR AERIAL ROBOTS

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Abstract

In this study, in order to enhance the accuracy of tracking repetitive maneuvers in Unmanned Aerial Vehicles (UAVs), a learning-based control scheme is proposed. At the outset, the controller is designed based on the sliding mode control (SMC) technique. In addition, the offline PD-type memory-based iterative learning control (ILC) is used along with SMC. The purpose of using ILC method is to reduce the effect of system uncertainty on the controller and decrease repetitive errors by adjusting the input control signal to dynamics and thus, to increase the reliability of following the desired path. In the ILC scheme, the error of states is saved during the maneuvers which will be used in the subsequent iteration. Also, in order to increase flexibility of the new control structure, ILC-SMC, a multilayer perceptron (MLP) has been developed. This network is designed to extend the control signal, generated by ILC, to similar maneuvers. The inputs of this neural network are the initial conditions for starting the maneuver and the output of the neural network is a gain that is multiplied by the stored control signal ILC and produces a new control signal. This generated signal will be suitable for similar maneuvers. The Levenberg-Marquardt (LM) algorithm has been used to train the multilayer perceptron artificial neural network. This method was then used in loop maneuvers. In this simulation, the difference between the maneuvers was in the acceleration of the maneuver, the radius of the maneuver, and the initial speed of the maneuver. This reduced the tracking error for similar maneuvers without performing the training process for the ILC control component. The presented control scheme is applied to a quadrotor aerial vehicle for tracking desired trajectories and it is shown that the vehicle is able to follow the desired trajectory better than the conventional SMC in the presence of uncertainties.

Key Words: Iterative learning control, sliding mode control, uncertainties, multilayer perceptron neural network, quadrotor (UAV).

NUMERICAL EVALUATION OF CAVITATION EROSION INTENSITY AROUND NACA0015 HYDROFOIL BASED ON EULERIAN-LAGRANGIAN APPROACH

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Abstract

In this study, to investigate the intensity of cavitation-induced erosion, the bubble behavior around the NACA0015 2D hydrofoil was simulated from the Eulerian-Lagrangian perspective. Macroscopic examination of the cavitation flow was determined by a homogeneous mixture model (Eulerian method) and the trajectory of bubble motion based on the applied forces using Newton's second law and the development of numerical code (Lagrange method). One way to reduce the computational cost of the Lagrangian perspective is to use the Discrete Phase Model (DPM). In this method, the fluid is considered as a continuous environment, while the discrete phase is solved by tracing a large number of particles in the calculated flow field. The behavior of the bubble arises from the pressure gradient caused

by the flow. Bubble oscillations were obtained from the modified Rayleigh-Plesset-Keller-Herring equation. This equation considers the compressible behavior of the bubble as the bubble collapse velocity approaches the speed of sound as well as the slip velocity between the bubble and the moving liquid. To pair the obtained results and solve them, the fourth-order Runge-Kutta method with variable time step was used, which increased the data solution speed up to 10 times. From the Keller & Kolodner relationship, a pressure wave emitted from the collapse of a spherical bubble, and the model of Soyama et al., the total energy of the cavitation-induced shocks, which is the result of the accumulation of all the shocks on each other, is obtained. The actual effects of flow for cavitation inception and erosion were investigated. Different cavitation numbers were used for cavitation inception with different radii. The results showed that the nucleation process occured in the cavitation inception numbers and the cavitation inception for flow with larger nuclei was visible better. As the cavitation number decreases, the bubble growth rate increases and as the bubble radius increases, the erosion intensity increases. At high cavitation numbers, the bubble oscillates around its initial radius; however, at the lowest cavitation number in this article, the number , we see an increase of nearly times the radius compared to the original radius. The erosion power of bubbles with an initial radius of 200μm is approximately 10 times that of the erosion power of bubbles with an initial radius of 100μm and about 100 times that of the initial bubbles of 50μm . The probable site of erosion is at the end of cavity at the hydrofoil level. As the bubbles increase in size, the number of collapses and their strength increase, and the dispersion of the distribution at the hydrofoil surface increases. The results were compared with other published works and had acceptable accuracy.

Key Words: Cavitation flow, eulerian-lagrangian method, erosion intensity, bubble dynamics, numerical prediction.

MECHANICAL AND ELECTRICAL SENSITIVITY OF A CAPACITIVE MICRO ULTRASONIC TRANSDUCER CONSIDERING SCALE EFFECTS

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Abstract

In the medical field, ultrasonic imaging is especially popular for its technological features, such as non-radioactive real-time acquisition, affordable equipment cost, and miniaturization capabilities in minimally invasive methods. However, in ultrasonic imaging, micromachined capacitive ultrasound transducers with consideration of various benefits such as ease of fabrication, integration with signal processing electronics, efficient performance, low impedance, and high transduction coefficient can be used for the high-frequency range of medical applications. In this paper, the mechanical and electrical behaviors of a capacitive micro ultrasonic transducer and the frequency bandwidth and sensitivity of the system are evaluated by consideration of scale effects. Moreover, the static deflection of the micro plate using COMSOL software and MATLAB script is extracted. To design an ultrasound transducer capable of producing high-resolution images, a micro capacitive structure using MEMS technology is required. In other words, in the development of medical devices including CMUTs, a range of the operating frequencies are crucial since this directly affects its resolution of images and applications. Consequently, in this work, in order to predict the mechanical behavior of this system accurately, the pull-in instability and frequency response of the diaphragm are investigated by considering the higher order gradients theory based on the Galerkin method. In fact, a simplified strain gradient elasticity analysis was used to analyze a circular micro-scale Kirchhoff plate, adding a role for intrinsic lengths in determining the behavior of the structure significantly. On the other hand, the pull-in voltage, resonance frequency, and the geometrical properties of the structure are the key parameters for designing a transducer. Hence, for a comprehensive study,

the electrical features of the capacitive micro transducer including electromechanical coupling coefficient, output pressure, and sensitivity of the received signal are studied by considering the high-order gradients theory. An effective, simple and accurate modeling for a micro/nano structure is presented in this paper, which can be used for medical applications.

Key Words: Medical imaging, micro electro mechanical system, capacitor micro-machined transducer, high order gradient theory.

MODELING OF A WIND ENERGY HARVESTING INVELOX SYSTEM BY COMBINATION OF NUMERICAL RESULTS AND SEMI-ANALYTICAL FRAMEWORK

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Abstract

In the current study, the 3D mesh generation and numerical solution of the flow within an INVELOX system, a modern wind energy harvesting structure, was presented. Based on the numerical results, a semi-analytical BEM framework was developed to model the aerodynamics and to estimate the performance characteristics of the system. It is implemented via an offline coupling mechanism. A particular and optimum blade shape was designed to be installed in the venture section of the INVELOX system. It was performed based on the prescribed sections mentioned in the literature. Considering the Prandtl's tip and hub loss factors as well as the Glauert's and Berton turbulent wake corrections, the behavior of the power coefficient and force coefficients were depicted. A comprehensive study was organized in terms of the tip speed ratio and the normalized length or dimensionless radius. From validation study, it was concluded that both numerical and analytical approaches were in acceptable agreement with the experimental and prior approved data. Based on these results, one may deduce that wind velocity can be magnified by about 70 percent by the Invelox system in the venture section. It is considerably more than the traditional ducts or shrouds used for wind acceleration. In order to make a comparison among the turbulent wake correction formulas, according to the proposed semi-analytical code results, it was found that the Berton and Glauert models would make a maximum difference of 15 percent when the power estimation was expected. By using this proposed hybrid model and related numerical and analytical frames, it is definitely possible to conduct the optimization study considering all the geometric and environmental parameters.

Key Words: Wind energy, INVELOX system, numerical solution, semi-analytical code, Prandtl correction, turbulent wake correction.

OPTIMIZATION OF THE COLEBROOK-WHITE EQUATION BASED ON EXPERIMENTAL DATA

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Abstract

Friction plays an important role in velocity distribution, shear stress, boundary layer, energy loss, and erosion. In the pressure drop, the friction factor has a direct relation with the Reynolds Number in smooth, turbulent, and transitional flows from the transition to the turbulence. Today, among engineers and researchers in fluid science, due to its wide applications, accurate calculation of the relations governing the friction factor is of high significance. Many attempts were made to improve the most famous friction factor equation, named Colebrook Equation, in the last century and since the , the experimental data have not been fully enriched with experimental data in various Reynolds regions. The purpose of the present study was to improve the Colebrook implicit equation, provide a more accurate equation in

the wider Reynolds Region, and adapt it to valid experimental and laboratory data. Therefore, the current researcher tried to perform the calculations with the least changes to the equation of Colebrook explicit and with the greatest accuracy using the experimental data. The method used in this research utilizes graph engineering software, and the first-generation solution method such as one of the three conventional methods matches the approximations and adjusts the curves to the obtained data. The number of errors in different equations in all Reynolds regions, specifically, the last equations presented, was investigated and researched as the last accurate and practical equations presented. Then, with the obtained information, the present research equation was corrected and matched with experimental data. Finally, in order to prove the accuracy of the equation of the present study, the accuracy was compared with other equations and diagrams were drawn in all common Reynolds regions. The results indicate the advantage of using this research and its equation accuracy in specific Reynolds regions compared to other equations. Accuracy and adaptation are much higher than previous values in the widely used areas.

Key Words: Friction factor, colebrook equation, reynolds number, moody chart.

THREE-SPHERE SWIMMER IN TWO DIMENSIONS AT LOW REYNOLDS NUMBER CONDITION

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Abstract

Being widely ubiquitous in fluidic mediums from aquatic environments to bodies, for the sake of their mobility, microorganisms, such as bacteria and motile cells, make use of particular swimming strategies that are counter-intuitive to that of our daily life experience, given that the physics governing micrometer is different from that of macroscale physics. Living in this particular realm of supposedly zero Reynolds number, these microscopic creatures are constrained such that their methods of swimming as well as their sequence of strokes need to utterly satisfy the so-called scallop theorem.
Considering the importance of motility for both microrobots and living creatures, this study aims to propose a model swimmer for artificial swimmers that might also be a prospective model explaining a mode of swimming for existing self-propelled natural living matters that can move forward by changing the shape of their body. The proposed swimmer is made up of three equal spheres, arranged in a triangular configuration by placing the center of each of them at the vertices of a triangle. The active links form a T-shape frame, such that the first link serves to connect two spheres, and the second link originates from the other sphere to connect it to the middle of the first link. Considering only two degrees of freedom for each link, this swimmer can translate along a straight path, by expanding or contracting its links consecutively in proper order. Obtaining the velocity of the swimmer, we study the effects of geometrical parameters of the triangle on the mean velocity of the swimmer over each cycle of motion. Finally, it will be shown that the velocity obtained here, which linearly depends on its characteristic parameters, resembles perfectly its well-known rectilinearly configured spheres counterpart, initially proposed by Najafi and Golestanian (Phys. Rev. E 69, 062901 (2004)), and its properties have been extensively studied over past years.

Key Words: Low reynolds number, microswimmer, motility at low reynolds number, microrobot.

NUMERICAL AND EXPERIMENTAL STUDY OF A WING COMBINED WITH WING GRIDS IN LOW REYNOLDS NUMBER FLOWS

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Abstract

One of the reasons for the increase in induced drag is the vortices created at the wing tip, which has a significant effect on reducing aerodynamic efficiency. Therefore, in order to reduce vortices and the induced drag as well as to improve the aerodynamic performance, the use of wing grid is recommended. Wing grids perform better at low Reynolds numbers, and combination of parameters such as taper ratio, aspect ratio, and twist has a better effect on wing performance and reducing turbulence intensity and induced drag. The purpose of this paper is to improve the aerodynamic performance of compound wing using the wing grids. In this study, the numerical and experimental approaches have been used to investigate the effect of these parameters and also, two key parameters: the grid dihedral angle and sweep angle. Also, a force balance test has been performed for force analysis and numerical solution validation. Wing grid dihedral angle decreases induced drag by increasing the space between separated tip vortices and prevents reinforcing effects due to superposition. On the other hand, dihedral angle should be arranged to increase the aerodynamic efficiency. In other words, increase in dihedral angle may defect the overall performance of the wing. The optimum configuration is found to be symmetric, where the dihedral distribution with a 40° angle for the first grid is reduced gradually to a value of -20° for the last one. In addition, sweep angle distribution for the obtained optimized dihedral angle is also investigated. Initially, each grid span is decreased from the first grid to the last at a constant rate. This increases the sweep angle and enhances the aerodynamic efficiency by 15%. Furthermore, the span of the side grids is reduced from the middle grid and marching the wing leading and trailing edges. Elliptical wing configuration has also been shown to increase aerodynamic efficiency by approximately 50%.

Key Words: Aerodynamic efficiency, wing grid, induced drag, dihedral angle, sweep angle, low reynolds number.

NUMERICAL STUDY OF CYLINDER DRAG COEFFICIENT REDUCTION USING PASSIVE FLOW CONTROL

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Abstract

In this study, the cylinder drag coefficient is reduced by using passive flow control. Installing a flat plate in two heights and different longitudinal distances in upstream flow increases the upstream flow momentum of the cylinder, leading to the higher boundary layer flow resistance against adverse pressure gradient which delays the flow separation. The flow separation delay enhances the pressure on the cylinder downstream. Then, the net pressure on the cylinder in the flow direction and, consequently, the cylinder drag coefficient are decreased. In case that the higher flat plate is utilized, the pressure on the upstream side is reduced more, leading to lower drag coefficient. However, for both heights of the flat plate at specific longitudinal distances from the cylinder due to the cavity flow formation between the cylinder and the flat plat, the vortex shedding is suppressed and the cylinder upstream is changed from the pressure side to suction side, leading to lower net pressure on the cylinder in the flow direction and as a result, less drag coefficient. At the optimal flat plate configuration at and , the minimum cylinder drag coefficient reached 90% reduction in comparison to the single cylinder case in the same flow condition. Results show that the drag coefficient reduction behavior is similar for different sub-critical Reynolds numbers due to the constant flow pattern and no considerable variation of the separation point. The entropy generation for the single cylinder and the case where the flat plate is located in its optimal configuration were investigated. The single cylinder has the highest entropy value, while the entropy of the optimal flat plate configuration with the cylinder reaches the lowest value, the same as the drag coefficient. Then, the drag coefficient is reduced by decreasing entropy generation, indicating the direct relation between drag coefficient and entropy generation.

Key Words: Drag reduction, vortex shedding, passive flow control, entropy generation.

ENERGY, EXERGY, AND EXERGOECONOMIC ANALYSIS OF POWER GENERATION CYCLE BASED ON INDEPENDENT GEOTHERMAL AND SOLAR ENERGY

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Abstract

The increasing energy demand in industrial and operational units and corresponding concerns about the limited fossil resources as well as environmental pollutions urge the researchers to generate electricity from renewable energy sources such as wind, geothermal, solar, and biofuels. In the present work, the use of solar and geothermal energy in producing electricity is investigated. The proposed cycle is capable of producing power by using both solar and geothermal energy sources simultaneously or can be used separately to generate electricity. Organic Rankine Cycles (ORCs), which benefit working fluids like refrigerants, have been employed. These cycles are able to produce electricity from low-temperature energy sources. The cycle is designed to employ two evaporators as high temperature and low temperature ones and, consequently, is equipped with two turbines as high and medium pressure ones. The governing equations of mass balance and first and second laws of thermodynamics were applied to each cycle component. A numerical code is written and solved by EES software. The performance of the proposed cycle was analyzed by energy and exergy viewpoints and the first and second law efficiencies were calculated. Therefore, the amount of exergy destruction and exergy efficiency of each component was defined. To evaluate the cost of the final product, which is electricity, exergoeconomic analysis, as an efficient tool, was carried out and the final cost of products was defined. Parametric study of the effect of different designing parameters, such as pinch point temperature difference and evaporator temperature on the energy and exergy performance and cost of the product was done. The obtained results showed that the best second law efficiency was related to high-pressure turbine, whereas the low-pressure turbine acquires the highest value of exergoeconimc factor. The average electricity production cost based on power generation in low- and high-pressure turbines was calculated as $28.32\frac{\$}{GJ}(0.102\frac{\$}{kwh})$.

Key Words: Solar energy, geothermal energy, economic analysis, energy analysis, exergy analysis.