Abstracts of Papers in English

HARDWARE-IN-THE-LOOP SIMULATION OF A GAS TURBINE ENGINE FUEL CONTROL UNIT USING MODEL-BASED PREDICTOR

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Abstract

Hardware-In-the-Loop (HIL) is a kind of simulation in which an actual component of a closed-loop control system is tested within computer-based real-time simulation of the rest of the system. In a conventional HIL simulation, the hardware is an Electronic Control Unit (ECU) in which electronic control signals are communicated between the hardware and the software. But, HIL simulation of a mechanical component, within a closed-loop control system, requires additional sensors and actuators named transfer systems. The transfer systems are used to connect the software and hardware parts. The HIL simulation can achieve unstable behavior or inaccurate results due to unwanted time-delay dynamic of the transfer systems. In this paper, a test bench is implemented for the hardware-in-the-loop simulation of the fuel control unit (FCU) of a gas turbine engine. The FCU is an electro-hydraulic actuator of the fuel control system. In a real engine, the FCU contains a miniature gear-type liquid-fuel pump which is driven at a fraction of the engine rotor speed mechanically by gears. In the HIL simulation, the engine is simulated numerically and an electric motor is employed to drive the pump of the

FCU. The real-time simulation of the gas turbine engine thermodynamic model is implemented on an industrial personal computer with an input/output board in connection with the electro-hydraulic system. There is time-delay in the forward path of the fuel control system due to the use of flowmeter for measuring the outlet flow rate of the FCU in HIL simulation. According to extensive experimental works, the AC motor's lag dynamics has no considerable effect on the HIL testing, and the flowmeter is the only additional transfer system of which the dynamic effect needs to be mitigated. The results show instability of the hardware-in-the-loop simulation due to unwanted time-delay of the flowmeter. Therefore, a model-based predictor is designed for time-delay compensation of the flowmeter. The consistency of the experimental real-time simulation and off-line simulation shows the applicability of the presented method for mitigating the effect of unwanted dynamic of the transfer system in the HIL simulation.

Key Words: Hardware-in-the-loop (HIL), Fuel control unit (FCU), gas turbine engine, model-based predictor.

NUMERICAL EVALUATION OF THE MECHANICAL PERFORMANCE OF INTELLIGENT ALLOY STENTS UNDER AXIAL LOADING FOR APPLICATION IN PERIPHERAL ARTERY

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Abstract

Stent placement has been a unique treatment for peripheral arteries illnesses in the recent years. Intelligent alloy stents can be used for peripheral arteries by reducing problems such as insufficient radial strength, low torsional capability and poor dynamic behavior compared to other stents. The application of the stent develops twofold chief objectives: undersized duration influence which avoids the effects of intimal division and the flexible shrinking and extended duration consequence which avoids restenosis due to the neointimal hyperplasia. Additionally, the other advantages of stent applications can be shortened as monitors: operative contour-capability to attain a satisfactory obsession to the vessel's wall; adequate resistance contrary to the flexible shrinking; fatigue asset due to the pulsatile current and physique's kinematics; a much smaller device to facilitate the percutaneous technique; small thrombogenicity; and height biocompatibility. In this study, metallurgical and mechanical behaviors of two types of intelligent alloys stent were studied by finite element method during the crushing process (axial loading) according to the standard. The intelligent stent material' model used to describe the material and mechanical behavior were based on the free thermodynamic energy of Helmholtz and the free thermodynamic energy of Gibbs. with varying the A_f temperature from 293 to 303°K (about 10°K), the difference between the upper and lower plateau stresses was about 40 MPa (equivalent to about 12%).The results showed favorable mechanical and clinical behavior of the stent with high Af temperature. Intelligent stents with high A_f temperature is shown to have the best mechanical performance for clinical applications owing to lower Chronic Outward Force (COF), higher Radial Resistive Force (RRF), and more suitable superelastic behavior. Model calculations showed that a high A_f temperature of Intelligent stent could exert a substantial effect on practical performance of the stent. This finite element model can provide a convenient way for evaluation of biomechanical properties of stents given to effects of intelligent alloys stents used in peripheral artery with respect to the effects of metallurgical, mechanical and clinical performance.

Key Words: Intelligent alloys, stent, peripheral artery, finite element method.

NONLINEAR FINITE ELEMENT ANALYSIS OF SKIN GROWTH USING HYPERELASTIC MEMBRANE MODEL

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Abstract
The aim of this paper is the formulation and numerical simulation of the growth phenomenon in skin under mechanical loading. The main feature and the novelty of the present research is that it models the skin as a membrane that obeys the constitutive equations of hyperelastic materials. Moreover, the membrane is not necassrily flat, and ca have arbitrary initial curvature in its reference configuration. At first, kinematics of membranes under large deformations is formulated and the essential tensors to be used in the next sections are introduced. Afterwards, fundamentals of the formulation of growth mechanics and its specialization for membranes are presented. In this work, growth phenomenon is characterized as an transeversely isotropic growth which accurs through a single scalar-valued growth multiplier which is defined in the surface where the growth phenomenon takes place. Growth parameter is considerd to be an internal varable that obeys a n evolution equation, which is a first-order differential equation of time. In addition, to solve the evolution equation for growth mltiplier, an unconditionally stable Euler backward method is employed. The compressible neo-Hookean strain energy density function is used to derive the expressions for the stress and the fourth-order elasticity tensors. For numerical solution of governing equations, a Total Lagrangian nonlinear finite element formulation is developed. Finally, as numerical examples, growth and large deformation of skin considering initially flat with three square, circular and rectangular geometries, as well as an initially curved cylindrical sector under external pressure loading is investigated. Even though the presented model in this paper is much simpler than the preceding ones, the obtained results are in agreement with those available in the literature. Moreover, numerical calculations and storage space are remarkably reduced by the present formulation, so that the number of membrane elements used in the present work is one percent of that of three-dimensional elements employed in the literature.

Key Words: Growth mechanics, skin, membrane, hyperelasticity, nonliner finite element method.

ANALYTICAL SOLUTION OF MASS TRANSPORT EQUATION IN RIVER NETWORK

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Abstract
In this study, by Laplace transform method, the analytical solution of the pollution transport equation in the limited domain for the river network to the upstream and downstream Dirichlet boundary conditions, and the initial condition of zero was extracted, and simulation was performed for two branch and loop networks with fixed and variable boundary conditions. After naming the nodes, by forming matrices of how to connect, flow characteristics and geometry of the river for each network as input to the problem, the diffusion matrix is created based on a function of the Laplace variable, which The value of the concentration in each node is calculated by solving the complex device created and using the inverse Laplace transform. Then, using the analytical solution extracted in a branch of the river for the pollution transfer equation, the analytical solution can calculate the value of pollution concentration at any desired location and time along with the river network. Finally, for validation, the analytical solution was compared with the numerical solution, and then the statistical error indices were calculated. The results indicate the optimal performance and high ability of analytical solution in modeling the two networks and its good adaptation to the numerical solution, which can replace numerical solution due to high accuracy and speed of calculations. Generally, due to common errors in numerical solutions such as numerical dispersion error, Round-off error, Truncation error of Taylor expansion mathematical sentences, analytical solutions, if any, for the river network are recommended over numerical solutions. Also, in the performed simulations, due to the change of the inlet flow and the flow cross-section to each, changes in the pollution concentration occur in the areas where the branches connect to each other, increasing or decreasing. The proposed

analytical solution for river networks can model more complex river networks and can be considered a criterion for the validation of numerical solutions. Also, the existing analytical solution can be used as a tool to validate other analytical solutions in the river network.

Key Words: Analytical solution, laplace transform method, advection-dispersion-reaction equation, river network, concentration distribution function.

SIMULTANEOUS ATTITUDE AND BENDING-TORSIONAL-VIBRATION CONTROL OF A SATELLITE WITH MULTI-SECTION FLEXIBLE PANELS USING PDE BASED BOUNDARY CONTROL-OBSERVER

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Abstract

In this paper a PDE observer based boundary control method is presented for attitude control and vibration suppression of a general form of flexible satellites considering torsional deflections in addition to bending for the first time. Attitude dynamics of the rigid hub together with the vibrations of solar panels form a coupled system of ordinary and partial differential equations which is controlled directly in this paper without discretization. Consequently, spill-over instability is avoided that may rise from the ignored vibration modes through simplifying partial differential equations into ordinary ones. The presented method requires the least number of feedbacks from boundaries which are estimated by the observer. Therefore, control system still uses information from vibrations in distributed parts while just attitude data shall be measured. Besides, no actuators excess to regular torque actuators in the main hub like reaction wheels are needed. Dynamic model is derived via Hamilton principle method which encompasses coupled ODE-PDE attitude dynamic equations plus the governing equations of torsional and bending vibrations. Bending deflections appear to be coupled with roll dynamics while torsional deflections affect pitch dynamics and vice versa. PDE observer is designed following the pattern of Luenberger scheme. After constructing error dynamics, Lyapunov stability criterion is applied to prove boundedness of observer states. Next, control laws are introduced that use boundary data estimated by the observer. Again a Lyapunov function is defined to cover total closed-loop system. Implicating Lyapunov stability criterion together with LaSalle invariance reasoning, asymptotic stability of the closed loop system is approved. Finally, finite element model of the satellite is obtained. Euler-Bernoulli beam elements are used in this regard and torsional generalized coordinates are added to them before calculating equivalent mass, stiffness and damping matrices of the dynamic system. Simulation of the closed-loop behavior illustrates good performance of this PDE observer based boundary controller.

Key Words: PDE observer, boundary control, flexible satellite, out of plane dynamics.

PROGNOSTICS OF ROLLING BEARINGS USING LSTM NEURAL NETWORK FOR PREDICTING THE TREND OF DEGRADATION SIGNAL

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Abstract

This paper proposes a remaining useful life (RUL) prediction method that uses the peak of the vibration acceleration signal as an appropriate feature to indicate the degradation process in the rolling element bearings (REBs). In the first step, this feature is transformed into a stationary time series using logarithmic transformation. That is because the long short-term memory neural network (LSTM-NN) works better with the stationary time series. Training the LSTM-NN is performed by this stationary time series as the input and the response is the training time series with values shifted by one time step. Therefore, the LSTM-NN learns to predict the value of the next time step at each point. In other words, to forecast the values of multiple time steps in the future, previous forecasted steps are used as inputs. Next, the values of the future time steps are returned to the main non-stationary form to predict the trend of the peak in the future. Importantly, new measured data can be used to perform new predictions. For this purpose, for every new measured data, the LSTM-NN repeats the mentioned steps and generates a new trend. This algorithm is a trend-dependent method. Therefore, an REB that has a slow degradation stage in its life, which is corresponding to the growth and expansion of defects in REBs, is appropriate to be studied by this algorithm. This method is implemented on two REBs from PRONOSTIA accelerated-life test which have been used by many researchers in the literature. According to the prediction results, the remaining time that peak amplitude trend touches a given threshold is provided. If this threshold is a criterion for the end of life (EoL), this method can be used to determine the RUL. The performance of the proposed method has been evaluated and the presented results are in a good agreement with the experimental data.

Key Words: Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM), Remaining Useful Life (RUL), time series forecasting, bearing accelerated-life test.

ACTIVE FLOW CONTROL IN DARRIEUS WIND TURBINE BLADE USING PLASMA ACTUATOR

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Abstract

Darrieus type vertical axis wind turbine is an appropriate choice for local electricity generation in urban environments. The major aerodynamical challenge in these turbines is dynamic stall which drastically affects the aerodynamic performance of the turbine. In this study, the effect of plasma actuator on aerodynamic performance of a Darrieus type vertical axis wind turbine was numerically investigated. Unsteady Reynolds-Averaged Navier-Stokes (URANS) equations were employed, accompanied with k-ω SST turbulence model. Suzen-Hoang model was used to model plasma actuator that calculates body force source term representing plasma actuator effects. The pressure-based finite volume method was utilized to solve the governing equations. First, the physics of dynamic stall in turbine blade was explored. Results show that the contribution of connection point moment in instantaneous moment of a blade is more than 25 percent. Moreover, counter clock-wise vortex in the suction side of blade was found to have a significant role in the blade's performance. To study plasma actuator effects, three test cases of inboard, outboard, and two side actuation, were considered and compared with the clean blade (no plasma actuator). The inboard plasma actuator weakened the dynamic stall vortex, increased lift, and decrease drag force in the down-stroke motion of the blade. Nevertheless, plasma has no effect during the up-stroke motion since the flow is attached to the blade's surface. The inboard actuation is effective for blade azimuth angles in the range of 70 to 180 degrees, and the outboard actuation is effective in blade azimuth angles between 180 to 290 degrees. In conclusion, plasma actuator leads to a 10 percent enhancement in power production for inboard actuation and two-sided actuation, but no significant effects were observed for outboard actuation.

Key Words: Vertical axis wind turbine, dynamic stall, active flow control, plasma actuator.

NUMERICAL INVESTIGATION OF AFFECTING PARAMETERS ON THE THERMAL AND DYNAMIC PERFORMANCE OF A HOT ISOSTATIC PRESSING FURNACE

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Abstract

Hot isostatic pressing (HIP) is a manufacturing process used in powder metallurgy science. It can be used to consolidate a powder, enhance the properties of a single crystal, solidify a cast blade in a specified direction and generally, densify a cold pressed, sintered or a cast part. The numerical simulation of the thermofluidic responses of working gases can provide important and detailed information about the dynamics of fluid flow and heat transfer in a HIP furnace. This information cannot be obtained from experimental observations. The experimental investigation of such a high temperature and pressure process is quite expensive. Moreover, the high working pressure and temperature limits the application of probes and sensors that may enable detailed data collection. This paper presents the modeling procedure and the results of a numerical investigation of a HIP furnace. The effects of the heater temperature, the performance of the cooling water system, and the presence of a radiation shield in front of the element were studied for two working gases. Moreover, investigation of the element heat flux and the temperature variation of the furnace could be used to choose a proper element and design an accurate control system. In order to increase the accuracy of the results, a real gas thermodynamic model has been also employed. In terms of physical modeling, the momentum and continuity equations and a two-equation turbulence model were coupled with the energy equation and radiation correlations. The results indicate that the final furnace pressure is directly influenced by the performance of the cooling system and the initial furnace pressure. A linear relation between the final and initial furnace pressure is observed. In addition, the final pressure is dependent on the type of the working gas whereas the temperature distribution is not significantly varied by gas selection. Based on the results, existence of the radiation shield causes non-uniformity in the flow field and temperature distribution of the hot zone area. The thermal conductivity of the furnace wall has a significant effect on the furnace heat loss. As the thermal conductivity increases tenfold, heat loss increases by 700 percent.

Key Words: Hot isostatic pressing furnace, numerical simulation, heat transfer.

NUMERICAL INVESTIGATION ON THE EFFECT OF INCREASING TURBULENCE INTENSITY AND CHANGING THE INJECTION ANGLE ON THE PERFORMANCE AND EMISSION OF CATERPILLAR MARINE DIESEL ENGINE

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Abstract

In this article, the effect of increasing turbulence intensity and changing fuel injection angle on performance and pollution of Caterpillar marine diesel engine has been investigated using computational fluid dynamics method in Fire software. To this end, two phase flow inside the diesel injector was simulated using the CFD.Solidworks software has been used for geometry creation and AVL-Fire software has been used for meshing and simulating. In order to increase the turbulence intensity, the groove inside the injector nozzle has been used and the fuel injection angle has been increased. Numerical results of injector and diesel engine simulation in operating conditions were compared with experimental data and a good agreement was observed between them. The results of diesel engine performance show that grooving, increasing turbulence intensity and fuel injection angle lead to a 75% increase in power and torque output and a 37% reduction in fuel consumption compared to the cylindrical fuel nozzle. Also, the results related to the pollution of this marine diesel engine show that in this case, the pollutants of carbon monoxide and nitrogen oxide decreasing 42.73% and 45.45%, respectively. Also, in this case, the engine has no problem in terms of producing soot pollutants and the soot produced during the combustion process is well oxidized. Then, in order to create a rotational flow and reduce the intensity of cavitation as well as the resulting erosion, the geometry of the cylindrical nozzle hole was changed to a converging cone and the groove inside it

was used. The numerical results show that changing the geometry of the nozzle hole and creating a rotational flow inside it leads to reducing the severity of cavitation and thus reducing the erosion and corrosion caused by it and increasing the life of the injector nozzle. Thus the fuel spray characteristics can be controlled by creation of swirly flow and changing the nozzle geometry and needle lift profile. Numerical results and experimental data validated from previous researches.

Key Words: Marine diesel engines, swirly flow, turbulence intensity, fuel injection angle, emission.

MODEL DEVELOPMENT FOR STARTUP AND DAMPING OF A STANDING WAVE THERMO-ACOUSTIC ENGINE

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Abstract

This paper presents a numerical method to evaluate the system conditions in transient mode for a standing wave thermo-acoustic engine (STAE). This method focuses on increasing the accuracy of predictions and creating a better eyesight of the operating conditions of these devices. Combining the numerical solution of transient mode with the electrical circuit analogy of standing wave TAE, is the main idea of this work. Electrical circuit analogy of STAE is done by assuming each component of a STAE as a lumped element. The result of Combining the time-dependent numerical solution and the electrical circuit analogy is a code, which determines the condition of startup, steady periodic, and damping regime of the spontaneous oscillations in the STAE. Accordingly, a nonlinear temperature distribution is obtained along the hot core. The developed numerical approach is in line with the experimental results of a STAE. Based on this method, the temperature variations along the stack and the impact of stack material on startup time and onset temperature are numerically investigated. Additionally, the onset temperature profiles are calculated and presented comparatively for the numerical and experimental results. The startup time of spontaneous oscillations is calculated for the standing wave system. Consequently, the best geometry that quickly reaches the sustained oscillations can be selected using this model. Examining the temperature profile during the startup and damping process highlights a temperature difference between these two processes. Observations show that using a material with lower thermal conductivity in the stack section can reduce the onset-damping temperature difference. Also, with the help of this method the startup moment of spontaneous oscillations was calculated as second in the system. The data obtained from the experimental tests and the temperature profiles resulting from the numerical solution method, showed a good agreement with each other for the onset and damping process in the system. The novel approach described here shows potential in capturing the onset-damping behavior of thermoacoustic systems efficiently.

Key Words: Thermo-acoustic engine, standing wave, onset process, damping process, electrical circuit analogy, numerical solution.