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Editorial

Modern numerical methods and their applications in mechanical engineering

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Numerical simulation is a powerful tool to solve scientific and engineering problems. It plays an important role in many aspects of fundamental research and engineering applications, for example, mechanism of turbulent flow with/without viscoelastic additives, optimization of processes, prediction of oil/gas production, and online control of manufacturing. The soul of numerical simulation is numerical method, which is driven by the above demands and in return pushes science and technology by the successful applications of advanced numerical methods. With the development of mathematical theory and computer hardware, various numerical methods are proposed. The new numerical methods or their new applications lead to important progress in the related fields. For example, parallel computing largely promotes the precision of direct numerical simulations of turbulent flow to capture undiscovered flow structures. Proper orthogonal decomposition method greatly reduces the simulation time of oil pipelining transportation. The development of commercial computational fluid dynamics (CFD) software also depends on the advancement of numerical methods. Thus, numerical methods become more and more important and their modern developments are worth exploring.

To reflect the frontier researches in numerical methods with applications, this special collection was established with the editorial team members from China, Italy, USA, and Norway. The guest editors are from both universities and industrial companies. The high quality and diversity of the editorial team members ensure the special issue collected 22 high-quality articles, from China, USA, Czech Republic, Turkey, Saudi Arabia, Korea, Vietnam, and India, providing a state-of-the-art insight to the specific topics including solid mechanics, fluid mechanics, optimization, and system stability.

In the article "Mechanical and failure characteristics of rock-like material with multiple crossed joint sets under uniaxial compression," Bonded-Particle Model (BPM) using PFC3D is used to explore the effect of joint sets number and joint spacing on the mechanical behavior of a jointed rock mass under uniaxial compression. Stress concentration is found to be the reason for relatively lower strength of blocks with crossed joint sets compared to the block with the same weakest single joint set. The results are helpful to reveal the mechanism of damage and fracture of jointed rocks under uniaxial compression.

In the article "Discrete element method simulations of load behavior with mono-sized iron ore particles in a ball mill," the sphere-clump method is employed to determine the geometrical shape of the mono-sized iron ore particles. Through discrete element method simulations, the impact of mill speed and lifter on the load behavior of iron ore particles in a ball mill not only potentially facilitates the improvement in high-performance liners but also optimizes the mill speed in the pre-design stage.

In the article "Lumped parameter model and numerical model of vapor bubble-driven valve-less micro-pump," a lumped parameter model for a vapor bubble–driven valve-less micro-pump is established and validated by the numerical simulation using ANSYS Fluent, in terms of bubble dynamics and flow performance. The results indicate that the lumped parameter model can be a convenient tool to guide the design of the micropumps.

In the article "On effect of viscoelastic characteristics of polymers on performance of micropump," a numerical modeling of polydimethylsiloxane (PDMS) micropump behavior using the fluid–structure interaction (FSI) along with viscoelastic material is demonstrated to capture FSIs accurately. The simulations can be extended for analysis of PDMS-based check-valve micropumps and other lab-on-a-chip devices under dynamic loading.

In the article "Applications of the discontinuous Galerkin method to propagating acoustic wave problems," the discontinuous Galerkin method is used to solve linearized Euler equations of sound propagation phenomena. The influence of mesh quality on convergence rate is studied. Through several benchmark problems and different boundary conditions, the method is proved to be efficient to this type of problems.

In the article "The effect of Knudsen diffusion and adsorption on shale transport in nanopores," a physics-based continuum model, considering gas transport mechanisms in shale reservoirs, is employed to simulate the flow transport in nanopores. The model is solved by lattice Boltzmann method with relatively low computational cost. Results indicate that Knudsen diffusion always plays a role in shale gas transport. This article provides a fast tool to estimate the correction factor in the Klinkenberg model in the field scale simulation of porous media.

In the article "Finite element analysis of the offshore reel-laying operations for double-walled pipe," bending characteristics of double-walled pipe during offshore reel-lay operations are investigated by finite element method. The numerical results give a reasonable understanding of how materials behave and the ranges of effective stress–strain. Through the numerical analysis, the possibility of successful spooling of pipe onto a reel can be estimated prior to actual operation with the desirable range of bending strain rate.

In the article "Numerical and experimental investigation on uniformity of pressure loads in labyrinth seal," the influence of pressure ratio and seal geometry on the uniformity of pressure loads on labyrinth seal teeth is studied. Based on the CFD and tests, the non-uniform seal geometry parameters are presented to improve the uniformity of pressure loads on teeth. It is found that the non-uniform clearances and groove width play positive roles in improving the uniformity.

In the article "Theoretical and experimental investigation on maximum pressure loads of labyrinth seal's teeth," a mathematical analysis formula is proposed to calculate the maximum pressure load on each tooth of labyrinth seal. Effects of teeth number, boundary conditions, clearances, and structure parameters on the uniformity coefficient are analyzed. A fitting method, which is in good agreement with the CFD results, is given to estimate the maximum pressure load on labyrinth seal teeth.

In the article "An improved numerical method for the mesh stiffness calculation of spur gears with asymmetric teeth on dynamic load analysis," the single-tooth stiffness and gear pair mesh stiffness for different types of spur gears with asymmetric teeth are defined. Numerical analyses via MATLAB and finite element shows dynamic gear loads are affected by mesh stiffness, such that designers may use the mesh and tooth stiffness results for the dynamic analysis of gears with asymmetric teeth.

In the article "Optimum design of fit clearance of proportional cartridge valve," design parameters of fit clearance between the spool and the sleeve are studied using finite element simulation and compared with experiments. Results show that the sleeve deformation under pressure is the decisive factor to optimize the fit clearance of the proportional cartridge valve while simulation accuracy can meet the engineering requirements for optimization.

In the article "Optimal design of heating system for electrical rapid heat cycle mold based on multi-objective optimization, multiple-attribute decision-making, and conformal design theory," an optimal design methodology of heating system is proposed to increase the heating efficiency and decrease temperature distribution of electrical rapid heat cycle molding (ERHCM) mold. The optimal design parameters of a single heated cell unit are obtained. The heating efficiency has been greatly improved while the warpage of the plastic parts is successfully reduced.

In the article "A study of evaluating an evacuation time," the computation of evacuation time for a fire protection system is discussed. Common parameters for fire sites are identified via simulation and regression. Results show that regression analysis is a useful method for evacuation time calculation and can serve as an assessment tool in fire accident–related scientific research and accident investigation.

In the article "Optimization study on combustion in a 1000-MW ultra-supercritical double-tangential-circle boiler," combustion process of one 1000-MW ultra-supercritical double-tangential-circle boiler is numerically studied, considering three-dimensional full-size structure of the boiler. The influences of primary and over-fire air velocity as well as the jet structure on NO_x generation characteristics are examined. Numerical results show that there exist two inverse elliptical flow fields and temperature fields. Current results may provide a theoretical basis for burner design improvement.

In the article "A study of combined finite element method simulation/experiment to predict forming limit curves of steel DP350 sheets," fracture height of experimental specimens and the corresponding in-plane major/minor strains of the finite element method simulation are adopted to estimate the forming limit curves of a steel DP350 sheet. Results show that the proposed forming limit curves could predict the fracture position with high accuracy and low cost.

In the article "Wavelet analysis of coherent structures and intermittency in forced homogeneous isotropic turbulence with polymer additives," wavelet transform method is performed to investigate the multi-resolution features of coherent structures and intermittency in forced homogeneous isotropic turbulence based on large eddy simulation database. Results show that the local contribution to intermittency in polymer flow is relatively small, leading to the suppression of intermittency in forced homogeneous isotropic turbulence with polymer additives.

In the article "Lagrangian mesh free finite difference particle method with variable smoothing length for solving wave equations," a variable smoothing length approach for updating the support domain size is suggested via the tested numerical method on the simple wave equation and the Burgers' equation in Lagrangian form. The proposed method with variable smoothing length is more accurate with different initial particle spacing, such that it needs fewer particles to maintain the same level of numerical error which costs less central processing unit (CPU) time in solving wave equations.

In the article "Direct numerical simulation of noninvasive channel healing in electrical field," a numerical model is established for the new concept of channel healing via adding small iron particles driven by an external electric field. Fluid–particle interaction in electric field and particle-wall interaction are discussed using direct numerical simulation. This numerical investigation provides valuable reference and tools for further simulation of real pipe healing in engineering.

In the article "Numerical simulation of micron and submicron droplets in jet impinging," concentric dual-ring deposition patterns of micron and submicron droplets are observed using the standard k-ε model, Reynolds stress model, and v^2-f model. The results show that the k-ε model fails to capture the turbulent flow structures and overpredicts the turbulent fluctuations near the wall. Reynolds stress model has a good performance in flow field simulation but still fails to reproduce the dual-ring deposition pattern. Only the v^2-f model reproduced the dual-ring pattern when coupled with droplet collision models.

In the article "Three-dimensional numerical study on flow dynamics characteristics in supercritical water fluidized bed with consideration of real particle size distribution by computational particle fluid dynamics method," the computational particle fluid dynamics method is applied to study the detailed flow behaviors inside a supercritical water fluidized bed, considering the limitation of the two-fluid method and discrete element method. According to the numerical results, the authors suggest that the diameter range distribution of particles should not be large in the practical industrial operations.

In the article "Dynamic modeling of SCARA robot based on Udwadia-Kalaba theory," a dynamic equation is established based on the Udwadia–Kalaba theory. Baumgarte stabilization method is used for constraint violation suppression to realize trajectory motion with high accuracy. Simulations of the varying law of the generalized coordinate variables and the trajectories of the SCARA robot are performed to fulfill the aim of dynamic modeling.

In the article "Interval element-free Galerkin method for uncertain mechanical problems," an interval element-free Galerkin method (IEFGM) is proposed to solve uncertainty problems. The advantage of the proposed method is that only node information is needed without requirement for element connectivity.

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