Study on multi-objective optimal operation of Jiangsu Section of South-to-North Water Transfer Project

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Abstract: Considering the water supply, economic cost and system stability of Jiangsu Section of South-to-North Water Transfer (E-SNWT) Project, this paper firstly develops an optimal operation model of E-SNWT Project with minimizing the total pumpage, maximizing the domestic water supply, industrial water supply and agricultural water, and minimizing the diversion peak as the objective functions. To overcome the shortcoming of poor diversity and easily falling into the local optimal solution of original Multi-objective Shuffled Frog Leaping Algorithm (MOSFLA), this paper proposed Multi-objective Quantum Shuffled Frog Leaping Algorithm (MQSFLA) based on real quantum coding, modified quantum gate updating strategy and dynamic external archive set. The model was solved by MQSFLA to develop an optimal operation scheme for E-SNWT Project. Compared with original MOSFLA, it shows that the MQSFLA performs is better both in diversity and convergence, more effective coordination of water supply and pumping under different scenarios, which can provide theoretical basis and scientific support for the operation management of E-SNWT Project.

Keywords: many-objective; Jiangsu Section of South-to-North Water Transfer; water resources optimal operation; multi-objective quantum shuffled frog leaping algorithm; dynamic external archive set

Prediction model for interactive time series evolution and its verification of dam deformation under Bayesian framework

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Abstract: Dam deformation is a result of the combined action of multiple risk factors at the same time. It is a common method for predicting deformation by using time series analysis to excavate the potential pattern of historical monitoring data. The existing prediction model for time series evolution of dam deformation is not only difficult to configure parameters, but also hard to integrate expertise, which leads to poor prediction. The solution presented in this paper is an interactive deformation prediction model (IDPM), which combines automatic prediction procedure and background knowledge of dam engineering field. Each decomposition item of the traditional additive model is refactored as the underlying structure of IDPM under Bayesian framework. The default values for model parameters are selected on the basis of numerical simulation to achieve automatic prediction. The artificial custom modeling is also realized by combining parameterized detection and intuitive parameters configuration. By means of visual fitting and statistical indicators to accurately reflect the source of prediction errors, model parameters are further modified to improve the practical applicability. In addition, taking a concrete dam as an example, the prediction circulation system of dam deformation composed by the above processes is used to effectively verify and analyze the accuracy, robustness and flexibility of IDPM. The model proposed would provide a novel method for prediction and analysis of the dam deformation safety.

Keywords: dam deformation prediction; time series analysis; Bayesian method; interactive modeling; parameterization

Numerical simulation of uniaxial compression failure process of river ice

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Abstract: In order to understand the intrinsic property of river ice, the river ice of Yellow River was sampled and carried out observation in freezing period, the uniaxial compression failure tests were accomplished. According to the results of physical test, the river ice was considered as a heterogeneous material consisting of grain, grain boundary and initial defects at mesoscopic scale. A numerical model was established to simulate the cracking process of river ice under uniaxial compression load. The effects of initial defect distribution and contents, grain size and other components of the river ice on its strength were analyzed. The results show that the uniaxial compressive strength of river ice decrease with the increase of initial defect contents, but the decreasing extent gradually slows down. With the increase of grain size, the uniaxial compressive strength decreases, and it has a linear correlation with the $d^{-1/2}$ of grain size. Compared with the physical experiment of the Yellow River ice, the results of mesoscopic model are in good agreement with the uniaxial compressive strength and cracking process.

Keywords: river ice; uniaxial compressive strength; numerical simulation; Yellow River

Study on the coupling model of cascade reservoirs' short-term optimal operation considering the influence of aftereffect

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Abstract: Given the coexistence of two operation modes ("electricity to water" and "water to electricity") of cascade hydropower stations, in this paper from the perspective of total energy, a coupling model of cascade reservoirs' short-term optimal operation is developed that combines the optimization criteria of maximum energy storage and maximum power generation. To improve the precision of model calculation, such influence factors as water flow hysteresis and the aftereffect of tail water level variation are considered by using BP neural network to accurately work out the downstream reservoir's inflow and the upstream reservoir's tail water level. Plus, we put forth Accompanied Progressive Optimality Algorithm to solve the proposed coupling model that considers aftereffect. Pankou-Xiaoxuan cascade reservoirs are taken as an example and the calculations show that the model can well fit the actual production thus enhancing the power generation benefits of the cascade hydropower stations. Compared with other existing algorithms, APOA has advantages in terms of computation time and calculation accuracy, which can meet the demand of practical production.

Keywords: short-term optimal operation; coupling model; aftereffect; Accompanied Progressive Optimality Algorithm

Ecological flow calculation in urban rivers and lakes base on synthesized ecosystem service function identification: model and application

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Abstract: For reasonable determination of the threshold of ecological flow of urban river and lake, an innovative model for urban ecological streamflow calculation based on synthesized ecosystem service function identification (i.e. MUSEF model) is developed, considering their basic characteristics, multiple ecological functional goals and hydraulic connections, reflecting the relationships between the consumption and non-consumption items, the stock and flux constitutes, the quantity and quality reactions. By setting multiple ecological function targets, the model can present the ecological flow time series, composition, variability, spatial distribution, and the degree of satisfaction under different scenarios, and provide a quantitative tool for ecology protection and health management of urban river and lake. Taking Zhuzhou city in China as an example, the monthly regime, composition and variation characteristics of ecological streamflow in typical river sections and lakes were quantitatively given, and the satisfaction degree and regulation requirement under different hydrological frequencies were analyzed to promote effective urban water management.

Keywords: urban river and lake; ecological streamflow model; synthesized function identification; monthly regime; variability; satisfaction degree

Dynamic coupling elasto-plastic analysis method for CFRD and compressible reservoir water based on SBFEM

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Abstract: Application of the scaled boundary finite element method (SBFEM) to simulate the flow in reservoir can reduce the dimensionality of solution by one dimension, and the effect of the water compressibility and the wave energy absorption of sediments can be considered. However, before the time domain analysis, the hydrodynamic pressure needs to be solved for multiple times in the frequency domain to obtain the time domain impulse response function, which requires heavy computation. In this paper, SBFEM is used to simulate the compressible reservoir water in front of dam, and the concrete-faced rockfill dam (CFRD) is discretized by finite element method (FEM). Then the dynamic coupling elasto-plastic analysis method for CFRD and compressible reservoir is established. According to the response characteristics of the dam-reservoir dynamic coupling system, the calculation process of hydrodynamic pressure is simplified with high calculation accuracy. Only the truncation frequency ω_T needs to be determined to sharply reduce the amount of calculation in the frequency domain. The results show that the higher the height of CFRD is, the more the computational efficiency is improved. The following advice is listed: $100\text{m} > H \geqslant 50\text{m}$, $\omega_T = 40\pi$; $200\text{m} > H \geqslant 100\text{m}$, $\omega_T = 30\pi$; $H \geqslant 200\text{m}$, $\omega_T = 20\pi$.

Keywords: hydrodynamic pressure; compressible water; SBFEM; simplify; truncation frequency

Construction of time-dependent drought index under changing environment and its application

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Abstract: In a changing environment, the drought index may appear the non-stationary characteristic. In this study, we assuming that the runoff series are second-order non-stationary sequences, a non-stationary model was established and optimized to fit the runoff observations and was used to calculate the Time-dependent Standardized Runoff Index (SRIt) that could reflect the drought characteristics in a river basin. The results show that SRIt based on the non-stationary model is more suitable for the evaluation of hydrological drought in the changing environment of Panjiakou Reservoir watershed. The SRIt value calculated by the non-stationary model is generally smaller than SRI value that calculated by the stationary model, which represents the more seriously drought degree. The main reason is that time-varying moment model can reflect the trend of runoff series under changing environment, which is caused by a series of factors affecting runoff, such as climate change, human activities and so on. Under the influence of these factors, the frequency and severity of hydrological drought events in Panjiakou reservoir basin increased.

Keywords: changing environment; hydrological drought; Standardized Runoff Index; Time-dependent Standardized Runoff Index; non-stationary

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Study on the dynamic interaction of earth dam-overburden-bedrock system

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Abstract: Many earth dams are planned to be built on overburden in the intensive earthquake area of West China. The earth dam-overburden-bedrock dynamic interaction is extremely complex because of the behavior of overburden soils such as dynamic nonlinearity and saturated characteristics. To study on the dynamic interaction behavior of dam-overburden-bedrock system, two different seismic input methods, the uniform excitation method (combined seismic inertia force and constrained boundary) and the nonlinear wave input method (combined nonlinear dynamic response of free field and nonlinear artificial boundary), were employed to conduct dynamic response analyses of earth dams built on overburden. The effects of series parameters, such as thickness and dynamic properties of overburden, strength and spectral behavior of seismic wave, were detailed studied. The research indicates that there is an outstanding error in vertical acceleration with uniform excitation method induced by the saturated behavior of overburden soils. The nonlinear wave input method is based on a more precise theoretical framework. The maximum vertical acceleration at dam crest obtained with this method is 20%~62% lower than that with uniform excitation method, and there is a larger error when the primary component of the input motion is high frequency. The maximum horizontal acceleration at dam crest with nonlinear wave input method is 5%~32% lower than that with uniform excitation method, and there is a smaller error when the effect of soil damping is obvious, there is a larger error when the primary component of the input motion has low frequency. The limit aseismic capacity of dams will be underestimated greatly with uniform excitation method. It is necessary to employed nonlinear wave input method to conduct seismic performance evaluation of earth dam built on overburden located at near-fault seismic zone where the vertical earthquake is prominent.

Keywords: overburden; earth dam; dynamic interaction; nonlinear wave input; vertical seismic response

Simulation of snowmelt runoff processes based on enhanced precipitation input module: Case studies in the Lhasa River basin

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Abstract: Precipitation is one of the most important components of mass balance and hydrological cycle in the natural systems and it is a dominant source of snowmelt runoff in the Alpine. Precipitation is also an important input variable for the snowmelt runoff model. It is, therefore, essential and significant to improve the accuracy of the precipitation in the snowmelt model. Qinghai-Tibet plateau is gauge scarce region and the meteorological stations are scarce to meet the demand of related studies. The meteorological station data are unable to describe the spatial and temporal distribution of precipitation. The precipitation lapse rate (PLAPS) is used in SRM to obtain the precipitation data in the different zones and the factors that terrain, wind direction, and water vapor will be ignored by the method of PLAPS. It is an important way to improve the accuracy of the snowmelt model by enhancing the module for input precipitation. A module of input precipitation was developed in this study by using the modified Successive Correction method in the semi-arid and alpine region, and it was coupled into the snowmelt runoff model. The new model was utilized to simulate snowmelt runoff in the Lhasa River basin. The results showed that the accuracy of the precipitation satellite was improved by modifying the precipitation module. The Nash-Sutcliffe efficiency coefficient values of the new model were 0.741 and 0.770 in the calibration period (2001-2007) and validation period (2008-2014). The values of Nash-Sutcliffe efficiency of streamflow using the new model were higher than the values of the original model, which indicated that this paper provided an effective approach to improve the accuracy of snowmelt simulation for gauge scarce basin in the semi-arid and alpine region.

Keywords: snowmelt runoff model; precipitation; data revision; Lhasa River

Coupled swash zone hydrodynamics and beach morphodynamics modeling I: Segmented sediment transportation model

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Abstract: In the study of coastal sediment dynamics, the formula of sediment transport rate is mainly based on the unidirectional flow. Therefore, it is difficult to deeply analyze the characteristics of sediment movement and its relationship with the evolution of beach morphology in the swash zone under reciprocating rapid unsteady flow. Based on the analysis of three formulas describing the Shields parameters of swash movement in swash zone, this paper analyzes the influence of vertical velocity, beach slope and seepage on the beach profile change. Moreover, an instantaneous Shields parameter correction formula that conforms to the dynamic characteristics of flow and sediment in the swash zone is proposed, and the calculation method of each parameter in the formula is determined. On this basis, the segmented formula of bedload transport rate for describing the sediment movement in swash zone is established. Based on the theoretical analysis and flume experiment, the formula parameters are calculated and the fitting parameter n is obtained, which should be located in the transition section of the lower and the middle swash zone. The results show that it is feasible to calculate the bedload transport rate by using sub-regional calculation, which lays the foundation for the establishment of beach morphodynamics model.

Keywords: swash zone; reciprocating rapid flow; sediment transport rate; Shields parameters; segmented formula

A method estimating natural runoff in regions with none or less data

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Abstract: Natural runoff is a key element for water cycle in river basin and hydrological calculation. Due to complex terrain, terrible weather, economic constraint or political effect, construction and management of hydrometric stations and discharge measurement is a rather tough thing in regions with none or less data. To solve this problem, river cross-section is initially classified as triangular-type and power-law-type, and then, according to hydraulic analysis, a regular formula associating water surface width and discharge has been deduced for both types. Combining remote sensing technique of real-time, efficient, large-scale and mass-data characteristics, a discharge estimating method for regions with none or less data has been presented. Further, it was tested with model experiment and field data. The results show that, for 56 groups of estimated discharge in experiments, the averaged relative error is 18.77% and the number that less than 20% is 40, whose ratio is 71.43%. For the estimated discharge according to field data, the averaged relative error is 20.71%. The ratio of relative error less than 20% is 64.66%, while that less than 30% is 86.03%. It indicates that the proposed method is an effective and accurate way to estimate natural runoff, providing a solution for discharge estimation in regions with none or less data.

Keywords: runoff; estimation; cross-section; hydraulic analysis; water surface width

Transient pressure fluctuations and runner loadings of a model pump-turbine during a load rejection process

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Abstract: During the load rejection process of pump-turbines, the pressure fluctuations and runner loadings force change sharply, resulting in frequent accidents. In this paper, the dynamic grid technique was used to simulate the load rejection process of a model pump-turbine, and the change characteristics of pressure fluctuations and unstable forces acting on the runner were analyzed. The results show the emergence and development of backflow patterns at the runner inlet greatly increase the turbulent kinetic energy of the fluid in the vaneless space, which enhance the rotor-stator interaction between the guide-vanes and the runner blades sharply, leading to a sharp rise in the amplitude of the pressure fluctuations. The maximum amplitude of pressure fluctuations is more than 5 times that of the initial stage. The turbulent kinetic energy of the local fluid in the vaneless space is enhanced by the backflows at the hub side of runner inlet, which make the distribution of high frequency components of pressure fluctuations along the height uneven. The backflows at runner inlet lead to non-uniform flows and rotating stall within the runner channels, which is the main reason for the rapid rises of the fluctuations of runner torque and radial force. Both their maximum amplitudes raise up to about 10 times and 60 times those of the initial stage. However, the influence of vortex rope in the draft tube is secondary.

Keywords: pump-turbine; load rejection; transient process; pressure fluctuations; unstable force