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Research paper

Simplified Computer Program for Ocean Wave Simulation

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Abstract

Analysis and design of structures located offshore involves the simulation of the ocean wave process in order to select a design load. This is a rigorous process that involves the solution of difficult mathematical equations. This study presents an efficient computer program for the simulation of the wave. The program was designed in such a way that only the wave parameters for a given location are required as input. The program then simulate the wave using Karhunen-Loeve series representation in which the eigenfunctions of Prolate Spheroidal Wave Functions are developed and used. The use of the program was demonstrated by simulating an example wave.

Keywords: *software program; Ocean waves; wave simulation*

1. Introduction

The rapid increase in the world population and the quest for modernization results in the increased demand for energy. This consequently forced the oil and gas exploration and production to move to deeper offshore fields and harsher operating environments. Consequently, various oil and gas exploration and production platforms such as jackets, jack-ups (Mirzadeh et al.), Tension Leg Platforms (TLPs) as well as semi-subs are used in offshore fields according to demand of the sites as well as safety and economic considerations. These platforms are classified on the Basis of their mode of operations as mobile or fixed structures. The fixed type such as Jackets and TLPs are stationed at a given exploration and production site and operate at the same site for their designed operational life, at the end of which they are decommissioned (Al-Ghuribi et al.). The mobile type of the platforms employs one form of mobility or the other to operate in various oil field during their design life (Yu et al.).

For the duration of their operation, offshore structures are expected to withstand the most severe storm expected to occur at least once in a given return period and to operate safely in any offshore location in which they are used. Consequently, the analysis, design and safety assessments of offshore structures involved the estimation of loads due to ocean waves. This is achieved by selecting simulating the most severe random design wave and using it to assess the performance of any structure under consideration. This design wave is usually represented by its two major statistical parameters, the significant wave height and wave period. The wave is then randomly simulated using any of the existing methodologies and extreme conditions from the wave are selected and used in the structural performance analysis (A Idris et al.).

Currently, no simplified software is available for the simulation of the wave in such conditions. The rigorous procedure involved requires a simple and easy to use software that allows an automated computations and simulation of the random wave to obtain the desired information. This study therefore aims to develop a simple computer software for the simulation of the wave and to evaluate its characteristics for use in offshore structural analysis and evaluations.

2. Method of Research

A framework for the simulation of the wave using Karhunen-Loeve Series (KLE) method (Ahmad Idris et al.; Sclavounos) in which the eigenfunctions of Prolate spheroidal wave functions (PSWF) (Osipov and Rokhlin)are used is described in figure 1. By reading the input parameters that includes the significant wave height, wave period and the spectral density model with its properties, the prolate spheroidal wave functions are generated. They are based on the spectral density model and the cut-off frequency of the spectrum.

3. Analysis and Discussion

Figure 2 shows the introductory page for the framework. In this stage, the description of the program is given. Information about input requirements and the simulations information were described. The user is required to type in the two wave parameters and select or insert the required wave energy density spectrum model.

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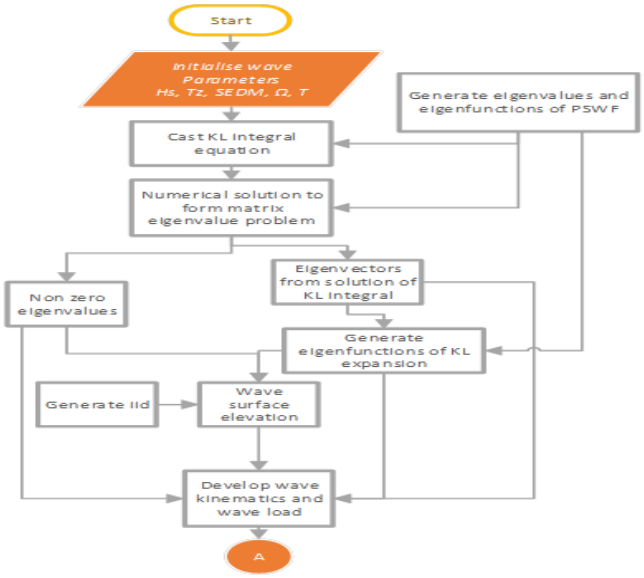


Figure 1. Flow chart for the wave simulation program

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%==========================================================================
                        %INTRODUCTION
%==========================================================================

%THIS PROGRAM IS DEVELOPED TO SIMULATE OCEAN WAVE USING KARHUNEN-LOEVE
%SERIES REPRESENTATION. THE PROGRAM RECEIVES INPUT IN FORM OF WAVE HEIGHT
%(Hs) AND WAVE PERIOD (Tz). THE USER THEN SELECT OR INPUT THE DESIRED
%SPECTRAL DENSITY MODEL FOR THE LOCATION OF INTEREST. THE PROGRAM THEN
%USES THE INPUT TO DEVELOP THE PSWF, CAST AND SOLVE THE FREDHOLM INTEGRAL
%EQUATION AND COMPUTE THE EIGENVALUES AND EIGENFUNCTIONS OF THE KLS MODEL.
%THE WAVE PROFILE IS THEN DEVELOPED AND THE WAVE KINEMATICS AND WAVE LOADS
%ARE COMPUTED.

%**************************END OF INTRODUCTION*******************************
clear                           %Clear the memory to start simulations
clc                             %Clean the screen to start simulations
tic                             %Time record starts

%****************************INPUT STAGE*************************************
Hs=7.7                          %Specificy wave height
Tp=9.6                           %Specify wave period
ohm=1.8                           %cut-off frequency of spectrum
%**************************************************************************
```

Figure 2: Introduction part of the software

The eigenvalues and eigenfunctions are then transmitted to the next stage, which is the KLS integral equation (Sclavounos)(Sclavounos). the integral is performed by numerical procedure by method of Gaussian quadrature. The solution of the eigenvalue problem was performed by simple algorithm for eigen-value solution and the results from the solution are used to model the wave profile.

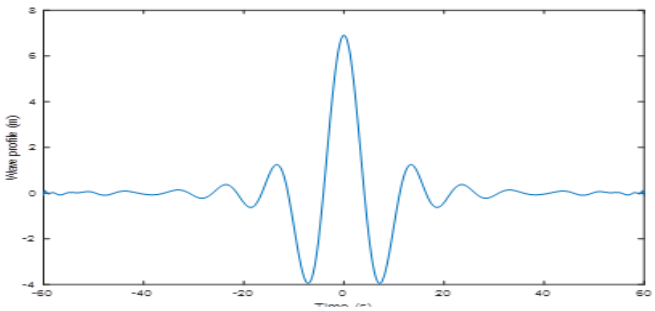


Figure 3: Sea state autocorrelation function simulated by the program

The presented program is used to simulate an example wave. A typical sea state with Pierson-Markowitz (P-M) spectral energy density model is used. The significant wave height and zero crossing period, as well as the cut-off frequency of 1.8rads/sec was specified. Figure 3 shows the rate of decay of the eigenvalues from the solution of the KLS integral equation and the first five eigenfunctions are plotted in figure 4. Consequently, it can be seen that as fewer as six terms are sufficient to keep in the expansion as subsequent terms closes in to zero.

Figure 3 shows the sea state auto correlation which was simulated by the program. In this figure, the random variables associated with the KLS expansion were taken as unity. The autocorrelation of the sea state represents the wave surface elevation at a point considered as origin, where the coordinates were taken as X=0. Time window of 120s was selected, which represents an adequate time for the propagation of the wave. The number of independent random variables involved in the expansion are taken as 10, based on the number of dominant eigenvalues from the solution of the KLS eigenvalue problem. In figure 4, the velocity profile was plotted as simulated by the program. The water depth was taken as 100m, which is an average depth for the operation of some offshore platforms. The wave velocity was simulated for the crest, which was positioned at time t=0s and trough at time t=8s. In the algorithm used by the program, the wave velocity can be obtained until the crest of the curve, with no stretching algorithms required. This enables the computation of the wave velocity and hence, the wave force above the still water surface.

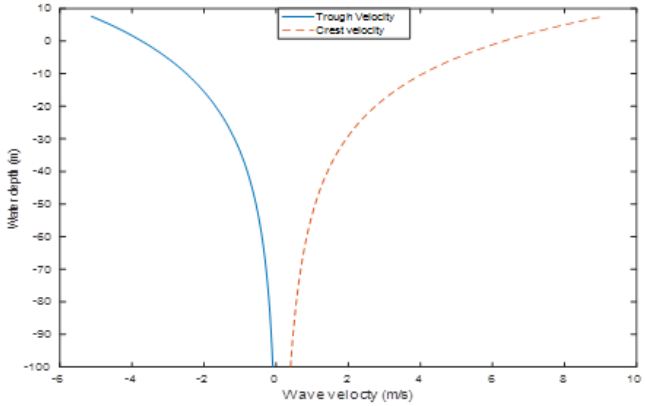


Figure 4: Variation of wave velocity with water depth at the crest and trough of the wave

4. Conclusion

This research developed a program for the simulation of ocean waves. It is an efficient program in which KLS expansion method is used. The program uses a miniml number of independent sources of uncertainty for greater efficientcy. The program is tested by simulating a sample wave profile.

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References

[1] Al-Ghuribi, T. M. Q., et al. “Decommissioning Decision Criteria for Offshore Installations and Well Abandonment.” Engineering Challenges for Sustainable Future - Proceedings of the 3rd International Conference on Civil, Offshore and Environmental Engineering, ICCOEE 2016, 2016.

[2] Idris, A., et al. “Efficiency of Trigonometric and Eigen Function Methods for Simulating Ocean Wave Profile.” Indian Journal of Science and Technology, vol. 10, no. 4, 2017.

[3] Idris, Ahmad, et al. “An Approach for Time-

[4] Dependent Reliability Analysis of Jackup Structures.” Cogent Engineering, vol. 4, no. 1, Cogent, 2017, doi:10.1080/23311916.2017.1409932.

[5] Mirzadeh, J., et al. “Performance of an Example Jack-up Platform under Directional Random Ocean Waves.” Applied Ocean Research, vol. 54, 2016, pp. 87–100, doi:10.1016/j.apor.2015.10.002.

[6] Osipov, Andrei, and Vladimir Rokhlin. “On the Evaluation of Prolate Spheroidal Wave Functions and Associated Quadrature Rules.” Applied and Computational Harmonic Analysis, vol. 36, no. 1, Elsevier Inc., 2014, doi:10.1016/j.acha.2013.04.002.

[7] Sclavounos, Paul D. “Karhunen-Loeve Representation of Stochastic Ocean Waves.” Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 468, no. 2145, 2012, pp. 2574–94, doi:10.1098/rspa.2012.0063.

[8] Yu, Q., et al. “New LRFD-Based Design Criteria for Mobile Offshore Units and Floating Production Installations.” Onepetro.org, https://www.onepetro.org/conference-paper/OTC-27225-MS. Accessed 26 Dec. 2017.