ACTIVE CONTROL OF THE RESPONSE OF ARTICULATED LEG PLATFORM TO RANDOM SEA STATE

by

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Submitted
in fulfillment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI
HAUZ KHAS, NEW DELHI - 110 016

JULY, 1997

To

PARTH

my loving son

who has shown a high sense of patience to keep off

his father

CERTIFICATE

This is to certify that the thesis entitled, "**Active Control of the Response of Articulated Leg Platform to Random Sea State**", being submitted by **Bharat P. Suneja**, to the Indian Institute of Technology, New Delhi, for the award of the Degree of "**DOCTOR OF PHILOSOPHY**" in Civil Engineering is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

!! *Verily all my thanks are for the almighty who brings success and succor* !!

I express my deep sense of gratitude to Prof. T. K. Datta for his untiring motivation, valuable guidance and constant encouragement throughout this study. His amicable nature and helping attitude turned three long years of hard work into a brief memorable span.

I am grateful to Shri L. K. Chaturvedi, honorable chairman, Engineering College, Kota, for allowing me to carry out the present study. I also wish to place on record my sincere thanks to my colleagues and teachers at Engineering College, Kota, specially to Prof. K.R. Arora, Prof. A.K. Arora, Dr. O.P. Chhangani and Dr. R.C. Mishra for their constant encouragement and valuable advises.

I acknowledge my heartfelt thanks to my friends, Mr. A. Shukla, Mr. M.M. Rao, Mr. Abhijit, Mr. S. Alam, Mr. A. Umar and particularly to Mr. Sarbjeet for the affection and ever available help provided by them. I can not forget the enjoyable company of my friends, Dr. Rajesh Deoliya, Dr. Rishindra Bisht, Dr. R.S. Adhikari, Dr. Rajiv Shrivastva and Mr. Manoj Kulshreshtha.

I am thankful to Mr. N.L. Arora and Mr. R. Agarwal for tracing the figures. My thanks are also due to Mr. Bhaskar and Mr. Duli Chand for their cooperation.

My sincere thanks are due to Dr.(Mrs.) S. Karunes for rendering full help and support to make my stay in Delhi comfortable. I also deeply acknowledge the hospitality extended by her to myself and my family. I am thankful to Prof. G. N. Tiwari and his family for the moral support provided by them.

I express my deep gratitude to my parents and uncle for their blessings which helped me reach my target. I am specially indebted to my parents-in-law, for their moral support and for taking care of my family in my absence, particularly for bringing up my infant son, PARTH. I am thankful to my brothers & sisters for their best wishes. Lastly but not the least, I tender my grateful thanks to my wife *Sangeeta* for her understanding, love and companionship and above all for the inspiration to initiate this project.

BHARAT P. SUNEJA

ABSTRACT

The compliant offshore structures are allowed to undergo large excursions to resist the environmental loads. So, appropriate control of such large displacement is necessary in order to minimize the risk of structural damage and also to improve their service conditions. The present study is undertaken with the object to develop different control strategies for the reduction of the response of such compliant offshore structures, like ALP, under the random sea-state. The control strategies include linear and nonlinear active control strategies with close and open-close loop configurations, and also the linear control strategies with improved performance function. The control laws for these strategies are, in general, obtained by minimizing some performance criteria (a function of state variables and the control force). In all cases, the standard Ricatti matrix equation is used to obtain the control law parameters.

The linear control laws are obtained by minimizing a quadratic performance function whereas minimization of a higher order performance function leads to the nonlinear control law. In the close loop control, the control force is taken as a function of only the structural response, whereas in the open-close loop control, the control force is taken as a function of structural response (as a feedback) and excitation variables (as feedforward). The linear control strategies with improved performance function are derived by incorporating the acceleration into the performance function. The linear close-loop control strategy is also extended to include the hydrodynamic damping in deriving the control law, by linearizing the nonlinear drag term.

Application of the open-close loop active control for the single hinge Articulated Leg Platform (ALP) under the random sea-state is made possible by defining the sea spectrum as a double filtered white noise like that used for describing the power spectral density function (PSDF) of random ground motions in the earthquake process.

Since a number of inherent nonlinearities are present in the response analysis of the ALP, an iterative frequency domain technique is used to obtain both uncontrolled and controlled responses of the ALP. The control force introduces additional nonlinearities in the system which in certain cases, lead to difficulties in the convergence of the solution. The iterative frequency domain solution is essentially obtained by the Newton-Raphson technique.

The efficiency of a control strategy is measured with a gain-value G, defined as the reduction in the response per unit control force, normalized to make it nondimensional; higher the value of G, better is the efficiency. The performance and efficiency of the various control strategies for a 180.5 m tall ALP tower under the random sea-state are investigated through a number of parametric studies under the variation of different controlling parameters. The various controlling parameters are weighting-index, r, for all control strategies; nonlinearity-weighting-factor, α, for the nonlinear control strategies; feedforward-weighting-factor, f_s, for the open-close loop control strategies; and the acceleration-weighting-factor, q_a, for the control strategies with improved performance function.

It is observed that the weighting-index, r, which penalizes the control force in the performance function, has a major influence in reducing the response; as r decreases reduction in the response increases. On the contrary, the G-value, in general, decreases with the increase in r. Thus, there exists an optimum value of the weighting-index, r, for which the performance of the control strategy is best in terms of both reduction in the response and the G-value. Over a certain range of r, the linear open-close loop control strategy provides a much higher reduction in peak displacement response which is significantly influenced by the feedforward-weighting-factor, f_s. The open-close loop strategy also provides significant reduction in the peak acceleration response which is not observed for the close loop control strategies. The effectiveness of these control strategies in reducing the peak displacement response could be further enhanced by using the nonlinear control law. The control force, thus obtained, consists of two parts: one is a linear function and the other a nonlinear function of the state variables. The participation of the nonlinear part is regulated by a nonlinearity-weighting-factor, α. The performance of the nonlinear control strategies is significantly influenced by the factor, α, particularly for higher values of r. For the nonlinear open-close loop control, increase in f_s does not improve the efficiency of the nonlinear control. The weightage of the participation of structural acceleration in the improved performance function for linear control strategies, is regulated by the acceleration-weighting-factor, q_a. The performance of these strategies with respect to reduction in the displacement response and the G-value is significantly influenced by the factor q_a. These linear control strategies are found to be more effective for high values of r. However, no significant gain in the reduction of structural acceleration is achieved by employing these control strategies.

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