Dynamic Analysis and Vibration Reduction Control for Structure with MTMD under Wave Action

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ABSTRACT

An optimal design method is proposed to determine the optimal mass, stiffness and damping coefficients of the multiple tuned mass damper (MTMD) for vibration reduction for structure under wave action. The time domain motion equation for wave-structure-MTMD (WST) system is established. By using modal transform and time-frequency domain transform, an explicit representation of the root mean square (RMS) value of displacement is derived. The simulated annealing algorithm is used to search the optimal parameters on goal of maximizing the reduction rate of the RMS value. With a numerical example, the proposed parameters optimization method is proved to be feasible.

KEY WORDS: Vibration reduction; optimal; MTMD; motion equation; modal transform.

INTRODUCTION

In harsh marine environmental conditions, wave forces acting on marine structure such as ocean platform and sea-crossing bridge tower are huge, therefore, the dynamic response of structure might exceed the permissible limits, which might lead to excessive deflections, accelerations, forces, and even failure. It is very necessary to study the dynamic interaction of sea wave and structure and to control excessive dynamic response to assure the safety and reliability of structure. Depending on the ratio of the structure projected member dimension to the wavelength, wave force is calculated either by the Morison equation, or by diffraction theory which describes the potential flow as a summation of the incident flow and the disturbance caused by the presence of the body. In this paper, because the ratio of structure dimension to the wavelength is small, it is appropriate to use Morison equation to calculate wave forces, and literatures in which the wave force is simulated using Morison equation will be discussed.

Studies on dynamic problem of offshore platform under wave action have been started from 1960s, in which a part of them (Bi, 1986; Zhong, 1987; Kawano, 1999) used frequency domain analysis method, and other part of them (Hahn, 1995; Yang, 1997; Mendes, 2003; Jia, 2008) used time domain analysis method. In recent years, with the rapid development of bridge technology, the constructions of sea-crossing bridges have been placed on the agenda, some studies have been done on the dynamic response of sea-crossing bridge tower under wave action. Zhang (2005) calculated the time history of wave forces on a pier foundation of a bridge. Liu (2009) established a dynamic calculation model of bridge tower under random wave action. In previous work, it should be noticed that some researchers didn’t consider the wave-structure couple effect induced from Morison's equation, the variation of the water surface causing the intermittency of the wave loading and variation of buoyancy forces on members in the splash zone.

In order to improve the survivability of structure under wave action, the single tuned mass damper (TMD) or MTMD was applied as vibration control device in the past several decades. The first study on TMD was published by Kawano et al (1992) who studied the response of a tuned mass damper and concluded that this damper is rather effective in decreasing dynamic response of structure due to wave action. Abdel-Rohman (1996) investigated the efficiency of some active and passive control methods to moderate the dynamic response of a steel jacket platform due to wave forces. Li et al (1999, 2000) presented an optimal design procedure of TMD for reducing the vibration of a steel jacket offshore platform excited by random wave forces. Li et al (1999, 2000) presented an optimal design procedure of TMD for reducing the vibration of a steel jacket offshore platform excited by random wave forces by frequency domain analysis. Shi et al (2003) proposed an optimal design method of TMD to control the first mode of the multi-mode structure. Patil and Jangid (2005) developed passive control systems for vibration control of an offshore steel jacket platform using energy dissipation devices such as viscoelastic, viscous and friction dampers. Kim et al (2006) analyzed the efficiency of TMD on the vibration control of a multiple degree of freedom (MDOF) structure under wave loading considering fluid-structure interaction by time domain analysis. Chen et al (2009) proposed a TMD design procedure to find out optimal damping and stiffness coefficient of TMD, calculation results showed the dynamic response of bridge tower under wave forces can be controlled effectively by TMD. In previous study, frequency domain analysis...