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Conditions of Visibility of Bridge Natural Frequency in Vehicle Vertical Acceleration

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Abstract

For structural health monitoring, selected bridges are generally instrumented and recorded data are utilized to obtain the natural frequency. However, this method is expensive and cannot cover all the bridges. Hence an alternative way for finding the bridge natural frequency is to utilize the vertical acceleration of moving vehicle. In the present paper spectrogram of vehicle vertical acceleration obtained theoretically has been analyzed to determine the conditions for which fundamental or higher mode bridge frequencies are visible. A flexible vehicle model moving along a simply supported bridge has been analyzed. Effect of vehicle / bridge mass ratio and surface roughness conditions on the visibility of bridge natural frequency have been investigated.

Keywords: *Natural frequency, structural health monitoring, spectrogram, flexible-vehicle model*

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1. Introduction

Natural frequency of the structures proves to be a reliable parameter in condition monitoring of structures as it reflects the reduction of stiffness due to damage when it drops down [1]. Bridge natural frequencies are usually determined by instrumenting a bridge with sensors and thereafter post processing the acquired sensor data. This method is a direct approach and costly. Moreover, all the bridges cannot be instrumented to acquire vibration data whereas vehicle fitted with an accelerometer can travel over different bridges. Identification of bridge natural frequency from vehicle acceleration data has been studied by several authors using acceleration spectra [2,3]. It may be noted that this indirect method of determining bridge fundamental frequency from moving vehicle acceleration is

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an attractive option; however, due to certain conditions of bridge deck and lower vehicle mass, results may not be promising [4]. Nguyen and Tran [5] apply a Symlet wavelet transform to the displacement response of a moving vehicle to identify the existence and location of cracks in a bridge. One of the most recent attempts at extraction of bridge frequency from a passing vehicle is based on optimization. Li et al. [6] develop a new theoretical method based on the Generalized Pattern Search Algorithm (GPSA) which is a typical search method in optimization. In the present paper, a flexible vehicle-bridge interaction model has been developed and solved using analytical technique with the help of symbolic computational software MATHEMATICA. Spectrogram of the vehicle acceleration has been utilized to detect bridge fundamental frequency.

2. Bridge-Vehicle Coupled System Model

In most of the past research, vehicle body has been modeled as rigid body. The model has been improved considering bending of the vehicle body in the present study. The full vehicle body along the length has been represented as Euler- Bernoulli beam with bending flexibility. The length of the vehicle is lv. The analysis is limited to the linear suspension characteristics. The bridge-vehicle model has been shown in Fig. 1.

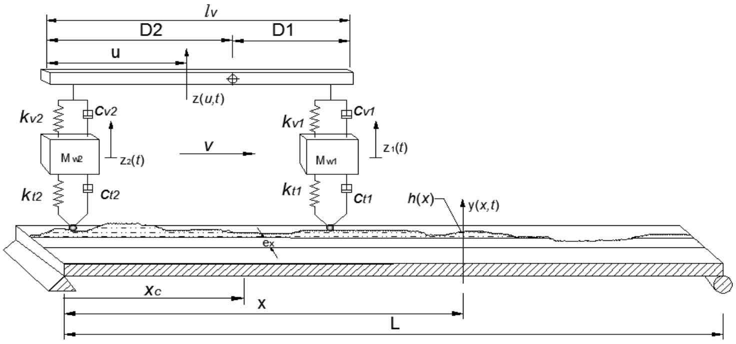

Fig. 1 Bridge subjected to Half Car vehicle Model

Vehicle centroid is located by the distance D_1 and D_2 measured from the trailing and leading edge of the vehicle body respectively. The governing differential equation of motion of the vehicle vertical deflection can be expressed as [7]

$$E_v I_v \frac{\partial^4 z(u,t)}{\partial u^4} + C_v \frac{\partial z(u,t)}{\partial t} + m_v \frac{\partial^2 z(u,t)}{\partial t^2} = f_v(u,t) \tag{1}$$

in which mv denotes the mass per unit length, , $E_v I_v$ is the flexural rigidity and C_v is viscous damping per unit length of the vehicle body, $z(u,t)$ represents vertical deflection of the vehicle body measured at location u from the reference point (taken at the left end of the vehicle) at time instant t. The vertical force imposed on the vehicle body is given by

$$f_{vF}(u,t) = \sum_{j=1}^{2} [k_{vj}\{z(u,t) - z_j(t)\} + c_{vj}\{\dot{z}(u,t) - \dot{z}_j(t)\}]\delta(u - u_j) \tag{2}$$

u_j represent the location of the attachment point of suspension from the reference point, $z_j(t)$ denote the vertical displacement of wheel, k_{vj} are the vehicle suspension stiffness, c_{vj} are the vehicle suspension damping. The subscript j =1, 2 represents the suspension location, for example j =1 denotes all quantities related to front suspension and j =2 for rear suspension. The equations of motion for two un-sprung masses are given by