Vibration Analysis of an Axially Moving Plate Based on Sound Time-Frequency Analysis

Qianqian Lu
Mechanical Engineering Department, Zhejiang University City College, Hangzhou, Zhejiang 310015, P. R. China.
Key Laboratory of Special Purpose Equipment and Advanced Manufacturing Technology, Ministry of Education, Zhejiang University of Technology, Hangzhou 310014, P. R. China.

Wei Shao, Yangfang Wu and Chunlin Xia
Mechanical Engineering Department, Zhejiang University City College, Hangzhou, Zhejiang 310015, P. R. China.

(Received 12 September 2017; accepted 11 December 2017)

In some types of non-contact measuring systems, vibrating motion has negative effects on accuracy. Therefore, there is a need to analyze and monitor the motion state of a moving part using a low-cost scheme. This study focused on the vibration analysis and monitoring of a poly-crystalline silicon solar wafer carried by a pair of parallel moving strings, separated by a distance. Based on the sound data series picked up by a low-cost microphone and using a time-frequency analysis method, namely, the Hilbert-Huang transform (HHT) method, the low frequency features of the moving wafer could be determined quantitatively. The results showed that the motion of the moving wafer was sensitive to speed and string tension. By comparison, the average marginal spectrum should be treated as the basis for quantitative vibration monitoring, especially for a system with a strict requirement in terms of motion smoothness.

1. INTRODUCTION

The dynamics of axially moving systems has been studied over many years. Recently, a review paper on the characteristics of axially moving continua has been published.1 Because of the complexity of the mathematical model of an axially moving plate, many types of numerical methods, such as the mixed Finite Element Method (FEM), modal spectral element method, and finite strip method have been used.2–8 In addition, Ghayesh and Amabili reported the geometrical nonlinear dynamics of an axially moving plate based on the direct time integration method.9 Using the pseudo-arclength continuation technique, Ghayesh et al. investigated the nonlinear dynamics of the forced motion of an axially moving plate and the effect of system parameters, such as the axial speed and pretension on resonant responses.10 The finite difference method, perturbation techniques, direct time integration, and pseudo-arclength continuation technique are also used to explore the nonlinear dynamic behaviors of moving continua.11–19 Considering viscoelastic characteristics, some researchers have taken an interest in viscoelastic moving panels, strings, plates, and webs.20–24

The characteristics of axially moving continua under special constraints have been reported. Based on the Von Kármán large deflection equations of thin plates, considering the influences of the axial movement of the plate, axial tension, fluid-structure interaction, and foundation displacement, and by adopting a numerical method and the approximate analysis method, Li studied the characteristics of 1:3 internal resonances and their bifurcations for an axially moving unidirectional plate, partially immersed in a fluid under foundation displacement excitation.25 Tang presented a vibration characteristic analysis and numerical confirmation of an axially moving plate with viscous damping.26 The complex frequencies, complex modes, and critical speeds of an axially moving plate, with viscous damping, were investigated using the complex mode approach. The effects of some parameters, such as viscous damping coefficients, axial speeds, aspect ratios, stiffness ratios, and support stiffness parameters, on complex frequencies and critical speeds were also examined. The natural frequencies, complex modes, and critical speeds of an axially moving rectangular plate, which is partially immersed in a fluid and subjected to a pre-tension, were investigated by using the classical thin plate theory.27 The nonlinear vibrations of an axially accelerating multi-supported string were discussed by using the Hamilton principle and multiple timescale methods.28

Experimental studies of an axially moving system have also attracted attention.29–35 The authors presented experimental results on the vibration characteristics of axially moving strings.32, 33 The vibrating characteristics of a moving plate were demonstrated by using the Hilbert-Huang transform (HHT) method.34 To quantitatively express the motion (including pitch and roll) of a moving plate, three capacitive sensors were used and a motion indicator was introduced.

In engineering applications, such as some types of non-contact measuring systems, vibrating motion has negative effects on accuracy; therefore, there is a need to monitor the motion state of the moving part by using a low-cost scheme. In the present study, through sound signal analysis, we focus on