Computer-aided design integration of a reinforced vibration isolator for electronic equipment’s system based on experimental investigation

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Received: 24 November 2005 / Revised: 11 January 2007 / Accepted: 14 May 2007 / Published online: 18 July 2007
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Abstract Electronic equipment’s system is always manufactured as a superprecision system. However, it will be used in harsh environment. For example, the computer in moving vehicles will be acted by vibrations. The objective of this paper is to provide a systematic investigation to test and computer-aided design of the vibration isolator for protection of electronic equipment’s system in harsh vibration environment. A micro-oil damping vibration isolator is designed and manufactured through coupling the oil and spring by ingenious tactics. The structure of the oil damping vibration isolator can achieve circulating oil damping function with an inner tube and an outer tube (some orifices are manufactured on upside and underside of the inner tube). The dynamics of the key model machine is systematically investigated. Based on the test, a nonlinear dynamic model for the vibration isolator is presented by analyzing the internal fluid dynamic phenomenon with respect to the vibration isolator. The model considers all the physical parameters of the structure. Comparisons with experimental data confirm the validity of the model. In the other, the model is integrated by introducing normalization measure. The normalization model shows the actual physical characteristics of the oil damping vibration isolator by considering quadratic damping, viscous damping, Coulomb damping, and nonlinear spring forces. An approximate solution is deduced by introducing harmonic transform method and Fourier transform method. Therefore, a parameter-matching optimal model for computer-aided design of the vibration isolator is build based on approximate solution. An example confirms the validity of the computer-aided design integration.

Keywords Vibration isolator · Dynamics · Model · Parameters matching · Computer-aided design · Reinforcement

Nomenclature

- $Q$: The oil flow rate between the two oil chambers
- $C_d$: Dynamic discharge coefficient (oil)
- $d$: Diameter of the oil orifice
- $\nu$: Kinematic viscosity of oil
- $F_f$: Estimation of the friction of the system
- $k_3$: Cubic stiffness coefficient of the spring
- $\gamma_1$: Correspond coefficient of the area of the orifice when circumfluence
- $\gamma_2$: Correspond coefficient of the diameter of the orifice when circumfluence
- $\omega_0$: Natural frequency of the vibration isolator
- $a_0$: Amplitude of excitation acting on the base
- $c_2$: Viscous damping coefficient
- $T_f$: Absolute acceleration transmissibility in vibration
- $Z(t)$: Relative displacement between mass block and base
- $\ddot{z}(t)$: Relative acceleration between mass block and base
- $\dot{z}(t)$: Relative velocity between mass block and base
- $\lambda$: Ratio between relative displacement and amplitude of excitation acting on the base
- $\lambda_0$: Amplitude of $\lambda$
\[ R_{01}; r_{11}; \] The first order Fourier expanding coefficient
\[ r_{21}; \] The first order Fourier expanding coefficient
\[ R_{02}; r_{12}; \] The first order Fourier expanding coefficient
\[ r_{22}; \] The first order Fourier expanding coefficient
\[ \xi_{1x}, \xi_{2x}, \xi_{f}, \xi_{fs}, \xi_{f_{opt}}, k_{10}, k_{30}, A_{g}, L, N, K_{1}, \omega, C_{1}, C_{f}, X(t), Y(t), \chi(t), \chi_{s}(t), \chi_{T}, \phi, \xi_{1}, \xi_{2}, \xi_{f}, k_{1}, k_{3}, \]

\( \xi_{1}, \xi_{2}, \xi_{f}, k_{1}, k_{3} \)

1 Introduction

Research on the design of vibration isolators or shock absorbers to improve the dynamic characteristics of electronic information equipment in moving vehicles or other carrier has rapidly increased in recent years. Most designs include a vibration isolator or shock absorber to attenuate vibrations so as to improve vibration safety. An accurate characterization of the vibration isolator is of paramount importance for sufficiently precise mathematical models of the shock absorber or vibration isolator for design purposes (Yang 2001; Narimani et al. 2004; Du Ploov et al. 2005; Du and Burdisso 2003; Cronje et al. 2005; Yang 2003, 2005, 2006; Yang et al. 2005, 2006; Ryaboy 2005; Kaul et al. 2005).

More recently, some literatures have discussed dynamics and design of vibration isolator or shock absorber in theoretical aspect or in test investigation. For example, Narimani et al. (2004) discussed frequency response of a piecewise linear vibration isolator. The result obtained by an averaging method is in agreement with numerical simulation and experimental measurements. Preliminary sensitivity analysis is conducted to find the effect of system parameters. It appears that the damping ratio plays a more dominant role than stiffness in piecewise linear vibration isolators. Du Ploov et al. (2005) discussed a tunable vibration absorbing isolator. The device is based on the liquid inertia vibration eliminator, which is modified so that the frequency at which maximum isolation occurs can be changed in real time. A theoretical model describing the device is derived using Lagrange’s equations. The model is used to design a practical device, and experimental results confirm the validity of the model. Du and Burdisso (2003) discussed passive and hybrid control of an isolator’s internal resonances to improve their vibration and noise isolation performance. This study proposes two approaches of using passive and passive/active or hybrid dynamic vibration absorbers directly embedded into an isolator to attenuate the IRs. (Cronje et al. 2005) discussed a variable stiffness and damping tunable vibration isolator. In this paper they report on the development of a variable stiffness and damping liquid inertia vibration eliminator vibration isolator. The result is the ability to shift the isolation frequency of the isolator and also to change the amplification at resonance. A practical variable stiffness spring was developed by using a compound leaf spring with circular spring elements. An experimental isolator was constructed and tested. The isolation frequency was shifted from 22.8 to 36.2 Hz by changing the stiffness of the spring by 270\%. A transmissibility of less than 10\% was achieved over the whole range. Yang (2003, 2005, 2006; Yang et al. 2006) discussed the performance and response of a shock absorber or vibration isolator with combined Coulomb damping, viscous damping quadratic damping and Duffing spring in humorous or random vibration excitations in theoretical and experimental aspect. A mathematical model of the multimedium vibration isolator is presented. An approximate solution was implemented to analyze numerical characteristics of the multimedium coupling vibration system. Some numerical characteristics of the system are shown by changing the parameters.

Some literatures have discussed optimal design of vibration isolator or shock absorber. Yang et al. (2005) discussed vibration reduction optimum design of a steam-turbine rotor-bearing system using a hybrid genetic algorithm. This paper describes the vibration optimum design for the low-pressure steam-turbine rotor of a 1,007 MW nuclear power plant by using a hybrid genetic algorithm (HGA) that combines a genetic algorithm and a local concentration search algorithm using a modified simplex method. The results show that the HGA can reduce the excessive response at the critical speed and improve the stability. Ryaboy (2005) discussed vibration control systems for sensitive equipment: limiting performance and optimal design. This paper reviews optimum vibration...