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Faculty of Mechanical Engineering

WIDEBAND NONLINEAR DYNAMIC VIBRATION ABSORBER USING PIECEWISE LINEAR STIFFNESS FOR EFFECTIVE STRUCTURAL VIBRATION SUPPRESSION

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Muhammad Harith bin Mustaffer

Master of Science in Mechanical Engineering

2020

DECLARATION

I declare that this thesis entitled "Wideband Nonlinear Dynamic Vibration Absorber Using Piecewise Linear Stiffness for Effective Structural Vibration Suppression" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ....

Name : MUHAMMAD HARITH BIN MUSTAFFER

Date : 30/11/2021

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : ....

Supervisor Name : Rosmidi Ramla

Date : 1/12/2021

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DEDICATION

To my beloved mother and father

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ABSTRACT

Vibration has become a major concern nowadays due to its tendency to produce undesirable noise and to potentially result in a harmful response. Generally, there are two ways to control the level of vibration in machines or structures. One of the techniques is by isolating the receiver of the vibration from the source. Isolation is a feasible solution if the level of vibration of the source cannot be altered. In some cases, the source of the vibration must be suppressed, hence isolation may not be a feasible solution. For these cases, the dynamic vibration absorber (DVA) is normally used. This is done by attaching another single-degree-of-freedom (SDOF) oscillating system onto the vibrating primary structure. The DVA is designed to have a natural frequency similar to the troublesome frequency of the primary structure. Many of the currently available passive dynamic vibration absorbers are not fully efficient in suppressing the vibration of the primary structure due to narrow operating frequency bandwidth. The performance of the DVA deteriorates even more in the application where the structure's troublesome frequency varies over time and it requires constant retuning of its natural frequency. Its low tolerance towards frequency mistuning may increase the level of vibration. Thus, it is necessary to design a DVA with efficient tuning capability and less sensitive towards mistune. In this study, the nonlinear dynamic vibration absorber (NDVA) with a tuneable piecewise linear stiffness mechanism which behaves similar to hardening stiffness mechanism was designed. The hardening stiffness is proven to perform better due to the larger suppression bandwidth. However, unlike the hardening stiffness mechanism, the proposed piecewise linear stiffness mechanism offers better tuning capability. The mechanism is composed of a cantilever beam constrained by two limit blocks which are adjustable in both horizontal and vertical directions. Firstly, the analytical study was performed before developing the NDVA to study its static and dynamic characteristics. The characterization study of the NDVA includes different limit block configurations (horizontal position and vertical gap), input amplitude, mass, and stiffness. Once the NDVA was fabricated, the analytical results were then validated experimentally by conducting quasi-static and dynamic measurements. The quasi-static measurement was done by exciting the base of the NDVA at low frequency to measure for force-deflection relationship. As for dynamic measurement, the base of the NDVA was once again excited on the electrodynamic shaker using sweep-up and sweep down of the excitation frequency between 10 Hz to 40 Hz. Finally, the performance of the NDVA in suppressing the vibration of the primary structure was measured and compared with its equivalent linear DVA. This was done by attaching the NDVA on the structure connected to the shaker and was excited using a similar range of sweep-up and sweep down excitation frequency. The results show a promising performance of the NDVA with an increase in suppression frequency bandwidth compared to its equivalent linear DVA.

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PENYERAP GETARAN DINAMIK JALUR LEBAR TAK LINEAR MENGGUNAKAN KEKAKUAN LINEAR SESECEBIS UNTUK PENYERAPAN GETARAN STRUKTUR YANG BERKESAN

ABSTRAK

Getaran telah menjadi kebimbangan utama pada masa kini disebabkan oleh kecenderungannya untuk menghasilkan getaran yang tidak diingini dan menghasilkan tindak balas yang berpotensi berbahaya. Secara umumnya, terdapat dua cara untuk mengawal kadar getaran pada sesebuah mesin atau struktur. Salah satu cara adalah dengan mengasingkan penerima getaran daripada puncanya. Pengasingan adalah cara yang sesuai jika tahap getaran pada puncanya tidak berubah. Dalam sesetengah keadaan, punca getaran mesti dikurangkan, oleh itu pengasingan bukan cara yang sesuai. Untuk keadaan ini, penyerap getaran dinamik (DVA) biasanya digunakan. Ia dilaksanakan dengan menghubungkan sistem getaran satu darjah kebebasan (SDOF) pada struktur utama yang bergetar. DVA ini direka supaya mempunyai frekuensi tabii yang sama dengan frekuensi bermasalah pada struktur utama. Kebanyakan penyerap getaran dinamik pasif sedia ada tidak berkesan sepenuhnya dalam mengurangkan getaran struktur utama kerana ia mempunyai lebar jalur frekuensi yang kecil. Prestasi DVA juga menjadi lebih merosot dalam aplikasi di mana frekuensi bermasalah pada struktur berubah-ubah mengikut masa dan sering kali memerlukan penyesuaian semula frekuensi tabiinya. Daya tahannya yang rendah terhadap salah suaian frekuensi akan meningkatkan lagi tahap getaran. Oleh itu, adalah perlu untuk mencipta sebuah DVA yang mempunyai kemampuan penyesuaian yang cekap dan kurang sensitif terhadap salah suaian frekuensi. Dalam kajian ini penyerap getaran dinamik tak linear (NDVA) dengan mekanisma kekakuan linear sesecebis boleh ubah yang mempunyai sifat yang sama seperti mekanisma pengerasan kekakuan telah direka. Pengerasan kekakuan ini telah terbukti lebih berkesan kerana mempunyai lebar jalur penyerapan yang lebih besar. Walau bagaimanapun, tidak seperti mekanisma pengerasan kekakuan, mekanisma linear sesecebis ini mempunyai kemampuan penyesuaian yang lebih baik. Mekanisma ini terdiri daripada jalur rasuk yang dikekang oleh dua blok penghalang, di mana jarak melintang dan jarak menegaknya boleh dilaraskan. Pertamanya, kajian analitikal pada NDVA dijalankan sebelum mereka bentuk NDVA ini untuk mengkaji ciri-ciri statik dan dinamiknya. Kajian pencirian ini dijalankan dengan menggunakan beberapa parameter seperti konfigurasi blok penghalang (jarak melintang dan menegak), tahap ketinggian masukan, jisim dan kekakuan. Setelah NDVA direka bentuk, hasil ujikaji analitikal kemudiannya disahkan secara eksperimen dengan menggunakan cara pengukuran seakan-statik dan dinamik. Pengukuran seakan-statik dilakukan dengan mengenakan getaran pada tapak NDVA menggunakan penggoncang pada frekuensi rendah untuk mengukur daya dan pemesongan. Untuk pengukuran dinamik tapak NDVA digetarkan mengunakan frekuensi menaik dan menurun antara 10 Hz ke 40 Hz. Akhirnya prestasi NDVA dalam menyerap getaran pada struktur utama diukur dan dibandingkan dengan DVA linear. Hasilnya menunjukkan prestasi NDVA yang baik dengan peningkatan lebar jalur frekuensi berbanding dengan DVA linear.

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