

THE PASSIVE VIBRATION ISOLATION SYSTEMS: ANALYTICAL INVESTIGATIONS

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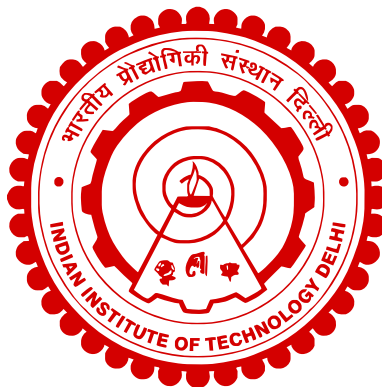
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THE PASSIVE VIBRATION ISOLATION SYSTEMS: ANALYTICAL INVESTIGATIONS

by

SUDIP CHOWDHURY
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Submitted
in fulfillment of the requirements of the degree of Doctor of Philosophy to the



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DECEMBER 2023

Dedicated to my mother Rina Chowdhury

THESIS CERTIFICATE

This is to certify that the thesis titled “**The Passive Vibration Isolation Systems : Analytical Investigations**”, submitted by **Sudip Chowdhury (2019CEZ8637)**, to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The optimum linear and nonlinear novel passive base isolators and tuned mass dampers are introduced in this thesis to mitigate the dynamic responses of the dynamic systems, such as single degree of freedom, multi degree of freedom systems and also to overcome the drawbacks of traditional passive base isolators and tuned mass dampers. Newton's second law applies to derive the governing equations of motion for the controlled structures. In addition, Lagrange's method applies to derive the nonlinear governing equations of motion of the nonlinear controlled structures. Taylor series expansion applies to generalize the nonlinear equations of motion of the controlled structures. The stochastic linearization method applies to linearize each nonlinear element of the governing equations of motion of the controlled structures. H_2 and H_∞ optimization methods are applied to derive the exact closed-form expressions for optimal design parameters of each novel passive vibration control device. The transfer function formation and harmonic balance methods are applied to derive the frequency domain responses of the controlled structures subjected to harmonic, random-white noise excitations analytically. Therefore, using these dynamic responses, the dynamic response reduction capacity of each novel passive vibration control device obtains in the frequency domain. In addition, a numerical study performs, considering the Newmark-Beta method, to further determine the dynamic response reduction capacities, such as displacement and acceleration reduction capacities in time domain. For this numerical study, the near-field with pulse and far-field earthquake records are applied as base excitations. The dynamic response reduction capacity of introduced passive vibration isolation systems are significantly at least 30% superior to the traditional ones. An analytical solver is introduced to derive the non-dimensional response spectra of impact oscillator. The impact between the floors of the two adjacent building structures or the impact between adjacent decks and abutments is modelled by an impact oscillator subjected to closed-form mathematical formulations of near-fault earthquake motions as pulse-type excitations. The momentum-based stereo-mechanical method is used as a contact force-based model to perform the impact analysis. The non-dimensional relative displacement between the impact oscillator and the barrier are determined as $\tilde{\delta} < 3$ for each successive impact.

HINDI ABSTRACT

गतिशील प्रणालियों की गतिशील प्रतिक्रियाओं को कम करने के लिए इस थीसिस में इष्टतम रैखिक और गैर-रेखीय उपन्यास निष्क्रिय आधार आइसोलेटर्स और ट्यून्ड मास डैम्पर्स पेश किए गए हैं, जैसे स्वतंत्रता की एकल डिग्री, स्वतंत्रता प्रणालियों की बहु डिग्री और पारंपरिक निष्क्रिय आधार की कमियों को दूर करने के लिए भी। आइसोलेटर्स और ट्यून्ड मास डैम्पर्स। नियंत्रित संरचनाओं के लिए गति के नियामक समीकरण प्राप्त करने के लिए न्यूटन का दूसरा नियम लागू होता है। इसके अलावा, लैंग्रेंज की विधि गैर-रेखीय नियंत्रित संरचनाओं की गति के गैर-रेखीय शासी समीकरणों को प्राप्त करने के लिए लागू होती है। टेलर श्रृंखला विस्तार नियंत्रित संरचनाओं की गति के गैर-रेखीय समीकरणों को सामान्य बनाने के लिए लागू होता है। स्टोकेस्टिक रैखिककरण विधि नियंत्रित संरचनाओं की गति के नियामक समीकरणों के प्रत्येक गैर-रेखीय तत्व को रैखिक बनाने के लिए लागू होती है। प्रत्येक नवीन निष्क्रिय कंपन नियंत्रण उपकरण के इष्टतम डिजाइन मापदंडों के लिए सटीक बंद-रूप अभिव्यक्ति प्राप्त करने के लिए H_2 और H_∞ अनुकूलन विधियों को लागू किया जाता है। विश्लेषणात्मक रूप से हार्मोनिक, यादृच्छिक-सफेद शोर उत्तेजनाओं के अधीन नियंत्रित संरचनाओं की आवृत्ति डोमेन प्रतिक्रियाओं को प्राप्त करने के लिए ट्रांसफर फ़ंक्शन गठन और हार्मोनिक संतुलन विधियों को लागू किया जाता है। इसलिए, इन गतिशील प्रतिक्रियाओं का उपयोग करके, प्रत्येक उपन्यास निष्क्रिय कंपन नियंत्रण उपकरण की गतिशील प्रतिक्रिया कटौती क्षमता आवृत्ति डोमेन में प्राप्त होती है। इसके अलावा, समय क्षेत्र में विस्थापन और त्वरण कटौती क्षमताओं जैसे गतिशील प्रतिक्रिया कटौती क्षमताओं को और अधिक निर्धारित करने के लिए, न्यूमार्क-बीटा विधि पर विचार करते हुए एक संख्यात्मक अध्ययन किया जाता है। इस संख्यात्मक अध्ययन के लिए, पल्स और दूर-क्षेत्र के भूकंप रिकॉर्ड के साथ निकट-क्षेत्र को आधार उत्तेजना के रूप में लागू किया जाता है। शुरू की गई निष्क्रिय कंपन अलगाव प्रणालियों की गतिशील प्रतिक्रिया कटौती क्षमता पारंपरिक लोगों की तुलना में कम से कम 30 % बेहतर है। प्रभाव थरथरानवाला के गैर-आयामी प्रतिक्रिया स्पेक्ट्रा को प्राप्त करने के लिए एक विश्लेषणात्मक सॉल्वर पेश किया गया है। दो आसन्न भवन संरचनाओं के फर्शों के बीच का प्रभाव या आसन्न डेक और एबटमेंट के बीच का प्रभाव एक प्रभाव थरथरानवाला द्वारा तैयार किया जाता है, जो पल्स-प्रकार उत्तेजनाओं के रूप में निकट-दोष भूकंप गतियों के बंद-रूप गणितीय फॉर्मूलेशन के अधीन होता है। प्रभाव विश्लेषण करने के लिए संवेग-आधारित स्टीरियो-मैकेनिकल विधि का उपयोग संपर्क बल-आधारित मॉडल के रूप में किया जाता है। प्रभाव थरथरानवाला और बाधा के बीच गैर-आयामी सापेक्ष विस्थापन प्रत्येक क्रमिक प्रभाव के लिए $\delta < 3$ के रूप में निर्धारित किया जाता है।

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