Preface

This book provides the reader with a comprehensive overview of the state of the art in vibration control and safety of structures, in the form of an easy-to-follow, article-based presentation that focuses on selected major developments in this critically important area.

Safety, reliability and long life of structures are the key points in engineering industries. Although many criteria for structural reliability exist, resistance to various types of dynamic loading is perhaps decisive among them. Thanks to progress in basic research in theoretical and experimental disciplines as well as in industrial development, protection against external dynamic influences need not only be passive, but can be applied through many active control systems. Consequently, the vibration control of structures is a crucial aspect of protection against sudden dynamic forces. Although the widespread introduction of digital control has meant phasing out of passive vibration diminution devices, both remain suitable and have a part to play in specific situations.

Structural vibration control is designed to suppress and control any unfavorable vibration due to dynamic forces that could alter the performance of the structure. Although many vibration control schemes have been investigated so far, questions involving their practical application, such as the use of advanced optimization techniques to control the vibration of structures, require further study. At the same time, it is necessary to realize that external environmental excitation processes are not only of a deterministic type, but are characterized by strong random processes. The two types of phenomena usually combine to form a complicated dynamic system, especially when the structure has to be considered in a nonlinear state. Such assignments require an analysis of the dynamic stability of the structure interacting with excitation sources.

In order to cover as much of the discipline as possible, the chapters of this book range from an enumeration of typical dynamic processes encountered in engineering practice to various styles of control in particular cases, highlighting the specific response processes of individual dynamic systems.

The field of vibration control of structures is, of course, much broader than the scope of presentation allowed for in this book. However, its contents represent a selection of typical topics discussed in this domain at the level of the basis of rational dynamics itself and applications in engineering practice, typified by the interaction of civil and mechanical engineering, with a possible overlap into theoretical and experimental physics.

In order to be successful in control and general management of the dynamic effects endangering civil engineering structures, it is necessary to evaluate statistics of the most serious events either of natural or operating origin. The first chapter, therefore, presents a balanced overview of structures and the causes of their failure due to disasters caused by the dynamic effects of wind, traffic, or earthquakes, due to insufficient knowledge of the dynamic behavior of structures, their complicated long-term interaction with environmental processes or material reliability, and, last but not least, due to inadequacy of standards and codes. As a consequence of these incidents, there have been significant changes in the codes and design philosophy of bridge construction in recent decades. The chapter illustrates progress in bridge engineering due to scientific and technological advances concerning the influence of wind, seismicity and heavy traffic. As the author points out, further research is still needed to mitigate the long-term effects of vibration and material degradation on the performance and integrity of bridge structures.

Chapter 2 studies a fractional distributed optimal (or sub-optimal) control for a class of infinite-dimensional parabolic bilinear systems evolving in a spatial domain Ω by distributed controls depending on the control operator. The main efficiency of the operator follows from a fractional spatial derivative of the Riemann–Liouville type. Using Fréchet differentiability, the existence of an optimal control depending on both time and space is emphasized. In principle, a quadratic function is minimized, which accounts for the deviation between the desired and the achieved state. Then, the characterizations of optimally distributed control for different admissible control sets are given. The chapter shows the importance of a strong theoretical background in dynamic models, particularly in the optimizing process, provided it is used in practice for reliable control. The authors developed and tested an algorithm materializing the above theoretical derivation. Subsequent simulations illustrate that the previous theoretical results are meaningful and can provide stable and practically applicable results.

A very interesting device that can serve to reduce structural vibrations due to various external shocks is based on the dry sliding phenomenon. Generally in physics and engineering, sliding represents both positive and negative effects with respect to the reliability and dynamic character of the system. For instance, bowed musical instruments are based on a complicated sliding force at the bow–string contact, which decreases with the velocity of the bow. In engineering, on the other hand, it can be understood as a very effective principle of energy absorption over a very large range of frequencies and amplitudes of relevant oscillations. This makes it an excellent candidate for various damping devices applicable in environments where excitations are extremely unpredictable in the frequency spectrum and amplitude content, e.g., anti-seismic facilities. These factors led to the invention in the mid-20th century of the sliding mode controller as an effective nonlinear controller for structures in seismic engineering, piping vibration damping, etc. However, practical implementation revealed that the sliding-based controller suffers from low sensitivity to uncertainties and other system variations due to chattering effects. Chattering is a harmful phenomenon because it leads to low control accuracy, high wear of moving mechanical parts, and high thermal losses in power circuits. In the first phase of the development of sliding mode control theory, the chattering was the main obstacle to its implementation. Thanks to the law of adaptation, this shortcoming was overcome by dynamically adapting the controller parameters depending on the system changes. Chapter 3 describes relevant research, numerical simulations and experimental measurements.

Another area that has seen intensive testing of dynamic effects is the suspension systems of softly sprung vehicles. In Chapter 4, a low-cost, customized, and effective damper dynamometer is constructed using computer-aided design and finite element analysis to measure the properties of suspension dampers used in a racing car. The chapter presents an excellent example of the advanced engineering process in the field, from construction design to race-track testing. Particularly inspiring is the description of the development of special equipment that had to meet strict requirements given the conditions in which it operates. The authors carefully follow the entire path of balanced design, manufacturing, testing and interpretation. Chapter 5 provides a typical example of complex nonlinear dynamic processes occurring in a non-conventional spherical absorber. Although passive absorbers have been investigated theoretically and experimentally many times and are commonly installed in practice, there are still many gaps in the information about new and progressive types. It is important to note that inappropriate configuration of a vibration absorber can not only reduce its efficiency but can even result in its negative influence. This is quite often the case, for example, with a passive or semi-active pendulum absorber when its spatial character is neglected. The system is strongly nonlinear and the interaction of the horizontal response components gives rise to complicated effects that can lead to various forms of stability loss.

A more sophisticated system, presented in the final chapter, is a ball-shaped absorber moving in a spherical cavity. This arrangement allows for many modifications. For instance, the cavity may be elliptical in shape, allowing the absorber to possess different eigen-frequencies in the principal directions, which is the usual disposition when the vibrations of a building require reduction. Another variant is a cylindrical absorber, as required for damping the horizontal vibration of a bridge deck. The spherical ball absorber is even more sensitive to dynamic nonlinear effects that cannot be avoided in the theoretical modeling of this system. Particularly interesting may also be the demonstration of Gibbs' principle of constructing the governing dynamic differential system, which in certain configurations leads to a more efficient system than that resulting from the direct application of the Hamiltonian principle to obtain a Lagrangian system.

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