

# Chapter 2

## Objectives

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**Abstract** Here, the intention of the monograph and the contents of the individual chapters are briefly presented.

This book aims to contribute to the development of industrially applicable SHM systems for thin lightweight structures made from glass and carbon fiber reinforced plastics and lightweight material systems which are already applied today and which will be increasingly used in various prospective engineering applications.

The content is compiled after intensive research of the authors and their PhD candidates on various research topics in the SHM area and gained in a joint collaboration over a period of roughly 10 years. So the main focus is on own research results which cover a broad spectrum of problems engineers are confronted with during the development and application of reliable and effective industrial wave based SHM systems for lightweight structures. However, the book is also built up as textbook enabling researchers, engineers, students, and interested readers to receive basic information, experiences, fundamental methods, and further important knowledge for understanding health monitoring techniques based on guided waves.

The book is subdivided into 21 Chapters which are ordered in 6 Parts. After this introduction in the current Part I, the most important theoretical principles, which are used throughout the book, are presented in Part II entitled “Foundations.” This Part comprises a systematic presentation of the analytical solution of the wave

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© Springer International Publishing AG 2018

R. Lammering et al. (eds.), *Lamb-Wave Based Structural Health Monitoring in Polymer Composites*, Research Topics in Aerospace,  
DOI 10.1007/978-3-319-49715-0\_2

equations for isotropic, anisotropic, and layered solids as well as the basics of the finite element method as a general numerical tool to analyze the propagation of waves and their interaction with damage. Additionally, an introduction to experimental techniques is given, e.g., to air-coupled ultrasound methods as well as to Laser Doppler vibrometry. These testing devices have become indispensable in experiments on wave propagation and thus for the understanding of physical effects in real engineering structures with all their imperfections as well as for verification of numerical results.

Part III, entitled “Efficient Numerical Methods for Wave Propagation Analysis,” presents the most promising methods for the numerical analysis of wave propagation and its interaction with different types of damage. It is shown that higher-order finite element methods and the fictitious domain method provide a powerful basis for the analysis of ultrasonic waves propagating in real engineering structures. The application of efficient numerical methods enables a deep understanding of the physics of wave propagation in layered orthotropic non-homogeneous structures and thus supplements experimental findings. Furthermore, numerical results provide imported information regarding the interpretation of the measured signals as part of the signal processing. Beyond that, these effective numerical tools are also required for the design and optimization of application-specific SHM systems.

Part IV, entitled “Continuous Mode Conversion,” deals with an unexpected and—from a physical point of view—very interesting finding. It was observed experimentally first that in the course of propagating ultrasonic symmetric waves in a CFRP structure a small amount of wave energy is permanently converted into an antisymmetric mode. Numerical analysis as well as sophisticated experiments helped to find the causes of this phenomenon and to explain it in detail. Signal processing and damage identification in CFRP structures become considerably more complex if continuous mode conversion appears.

In SHM technology the significance of signal processing can scarcely be overestimated. Therefore, special attention is given to this issue in Part V entitled “Signal Processing.” At first, methods for the localization of impact events and damages are presented and experimentally verified. In these investigations, a precise time-of-flight determination has shown to be of crucial importance so that a separate chapter deals with this aspect. The design of an SHM system requires accurate material parameters. Often, however, these parameters are not known and cannot be computed from the material parameters of the constituents in case of composite materials. Thus, their determination is subject of another chapter. Finally, this part of the book deals with the so-called dynamic load monitoring method which makes use of the fact that a structural damage acts as a source of a dynamic force. Its location is identified mathematically by solving an according inverse problem.

The title of Part VI is “SHM Systems” and indicates that various elements of an SHM system are considered as a whole. At first, mode selective actuator-sensor-systems based on interdigital transducers are presented and experimentally investigated. The advantage of this approach is that the interference of different wave modes is considerably reduced. Then the design of virtual sensors as well as

the overall design of an entire SHM network is presented and the interaction of the sensors and actuators with the propagation wave is investigated. Finally, a large industrially relevant shell section of an aircraft fuselage is presented. It is equipped with a network consisting of a large amount of piezoelectric actuators and sensors. The overall behavior of the system is tested and the quality of damage detection in a complex engineering structure is shown.

Lamb-Wave Based Structural Health Monitoring in  
Polymer Composites

Lammering, R.; Gabbert, U.; Sinapius, M.; Schuster, Th.;  
Wierach, P. (Eds.)

2018, XIV, 479 p. 286 illus., 201 illus. in color.,  
Hardcover

ISBN: 978-3-319-49714-3