Analytical Solutions and Experiments in Wave Propagation Problems

Thesis report submitted to

Indian Institute of Technology Mandi

in partial fulfilment for the award of the degree of

Master of Science

in

Design

by

Gaurav Sharma

(S16006)

Under the supervision of

Dr. Arpan Gupta
and
Dr. Aniruddha Chakraborty

School of Engineering

Indian Institute of Technology Mandi

Spring Semester, 2017-18

October, 2018

DECLARATION

I certify that

(a) The work contained in this report has been done by me under the guidance of my supervisor.

(b) The work has not been submitted to any other Institute for any degree or diploma.

(c) I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.

(d) Whenever I have used materials (data, theoretical analysis, figures, and text) from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references. Further, I have taken permission from the copyright owners of the sources, whenever necessary.

Date: October, 2018 (Gaurav Sharma)

Place: Mandi (S16006)

SCHOOL OF ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY MANDI

MANDI - 175005, HIMACHAL PRADESH, INDIA

CERTIFICATE

This is to certify that the project report entitled "**Analytical Solutions and Experiments in Wave Propagation Problems**" submitted by **Gaurav Sharma** (Roll No. S16006) to Indian Institute of Technology Mandi towards partial fulfilment of requirements for the award of degree of Master of Science in Design is a record of bona fide work carried out by him under my supervision and guidance during Spring Semester, 2017-18.

Date: October, 2018

Place: Mandi

Dr. Arpan Gupta
School of Engineering
Indian Institute of Technology Mandi
Mandi - 175005, Himachal Pradesh
India

Dr. Aniruddha Chakraborty
School of Basic Sciences
Indian Institute of Technology Mandi
Mandi - 175005, Himachal Pradesh
India

Abstract

Name of the student: **Gaurav Sharma** Roll No: **S16006**

Degree for which submitted: **Master of Science**

Department: **School of Engineering**

Thesis title: **Analytical Solutions and Experiments in Wave Propagation Problems**

Thesis supervisor: **Dr. Arpan Gupta**

Thesis co-supervisor: **Dr. Aniruddha Chakraborty**

Month and year of thesis submission: **October, 2018**

Every disturbance in a continuum media generates a wave, which propagates through the space-time domain. Therefore, the study of waves and its propagation is of the utmost importance for all engineering problems. Various studies have been performed in this domain. Analytical solutions exist for the simple cases and can be applied to most of the complex scenarios by using the superposition principle. A more complex problem can be solved using computational methods. But, each of them pertains to their own drawbacks. The response through a computational method needs the whole space and time domain to be analyzed. This approach provides good results but becomes inefficient when the solution is required at only a very distant time step. Also, some complex excitation become very cumbersome to be decomposed into superimposing components. Novel analytical methods are proposed for wave propagation problems to overcome the above mentioned limitations.

A modified Laplace Transform approach is proposed to investigate the wave propagation/ vibration response of a stretched string. The vibration response is demonstrated using the proposed method for various initial and boundary conditions. The method is capable of calculating the vibration response of a moving impulse loading on the string. The method is compared with other methods such as Fourier analysis and finite difference method for accuracy and computational efficiency.

A Dirac Delta function approximation is proposed to analyze the acoustic wave propagation through panel. Governing wave equation is modified to include the Dirac Delta function which represents the discontinuity in the wave propagation medium (air to panel). The expression for wave transmission, reflection, and absorption coefficients are evaluated for a single panel in terms of strength of the Dirac Delta. The obtained results are compared with Finite Element simulation results for a single-layered and multilayered panel materials.

Finally, one-dimensional acoustic transmission line has been constructed to experimentally measure the strength of Dirac Delta function for various test materials of panel. For this purpose, a Two Microphone Impedance Tube experimental setup is designed and constructed. A statistical study has been performed on the developed setup to minimize the errors in measurements. The sample calculations has been demonstrated for acoustic testing of different materials using the developed experimental setup.

Acknowledgements

I would like to express my gratitude to my supervisor Dr. Arpan Gupta for his valuable suggestions and feedback provided during my research work. The course work on Acoustics and Vibrations generated ripple of interest in this field. The coursework and discussions with him, strengthened my conceptual base in the field. I would also like to express my deepest gratitude towards Dr. Aniruddha Chakraborty, for providing me with constant guidance, especially on the existing analytical approaches.

I am highly thankful for the valuable suggestions provided by the APC members Dr. Vishal S. Chauhan, Dr. Rajesh Ghosh, Dr. Mohd. Talha and Dr. Pradeep Kumar. I am thankful for the necessary knowledge, wisdom and suggestions from Dr. Rajeev Kumar, Dr. Gaurav Bhutani and many other faculty members.

I would like to acknowledge the support provided by Mr. Raghav and the Mechanical Workshop staff, in the manufacturing of the components involved in making the experimental setup. I would also acknowledge the support provided by the finance department in the tendering process involved in the procurement of the quarter inch microphones.

I would like to acknowledge the Acoustics and Vibrations Lab, for providing me with ample environment and infrastructure to conduct my research smoothly. I am very grateful for the support provided by the lab members Saurabh Yadav, Preeti Gulia and Pankaj Shitole.

I am grateful to IIT Mandi for providing me with the scholarship and many more facilities during my research work. I am thankful to my friend Sharey, Ajay, Abhishek, Naman, Surbhi etc. for their constant encouragement and support.

Lastly, I would like to thank my parents, grandparents and sister for their patience and support during this work.

Gaurav Sharma

Contents