

**MEASUREMENT/ MONITORING OF  
VIBRATIONS USING DIGITAL SPECKLE  
PATTERN INTERFEROMETRY**

by

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**INSTRUMENT DESIGN DEVELOPMENT CENTRE**

submitted in fulfilment of the requirements of the degree of

**DOCTOR OF PHILOSOPHY**

to the



**INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

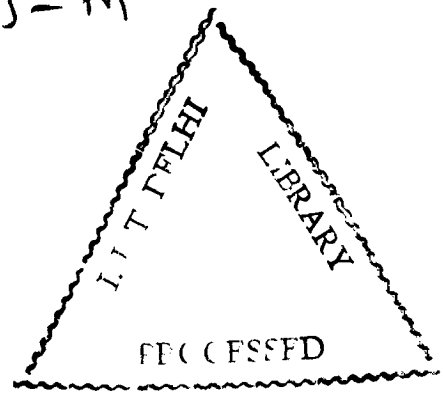
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Vibrations; Speckle Interferometry

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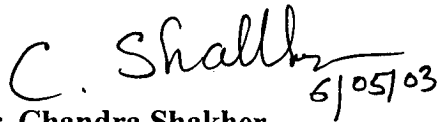
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# CERTIFICATE

This is to certify that the thesis entitled, “**MEASUREMENT/ MONITORING OF VIBRATIONS USING DIGITAL SPECKLE PATTERN INTERFEROMETRY**”, being submitted by **Mr. Rajesh Kumar**, to the Indian Institute of Technology, Delhi, for the award of the degree of “**DOCTOR OF PHILOSOPHY**”, is a record of the bonafide research work carried out by him under our supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of my knowledge has reached the required standard.

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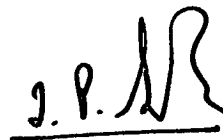
  
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# ACKNOWLEDGEMENTS

I express deep sense of gratitude to my Supervisor, **Prof. Chandra Shakher** for his invaluable guidance, keen interest, deep involvement and encouragement during all stages of research. Credit of introducing me to the area of digital speckle pattern interferometry goes to him. Apart from being a Ph.D. supervisor he remained guardian to me.

I am highly grateful to **Prof. R. S. Sirohi**, Director, **IIT Delhi** for his interest in the work and going through some parts of the thesis.

I am very much thankful to **Dr. I. P. Singh**, my co-supervisor for his constant encouragement and inspiration along with valuable suggestions through out my research work.

My special thanks are to **Prof. Kshitij Gupta**, Head, Mechanical Engineering Department of **IIT Delhi** for fruitful discussions and suggestions.

I am also grateful to **Dr. R. C. Chauhan**, Director, **Sant Longowal Institute of Engineering and Technology, Longowal** for providing me permission and necessary leave to undertake Ph.D. at Indian Institute of Technology Delhi. I am also thankful to **Prof. V. Sahni** of my department at Sant Longowal Institute of Engineering and Technology for moral support and encouragement. I also thank colleagues of my department who shared teaching load during the leave period. I particularly wish to thank my class fellow, personal friend and colleague of the department **Mr. R. K. Yadav** who

took pains to look after my official matters at SLIET, Longowal during the leave period, which helped me concentrate on my research work. Time to time help and encouragements from my close friends of various departments in SLIET is gratefully acknowledged.

Financial assistance from **All India Council for Technical Education**, Ministry of Human Resource Development, Government of India, is thankfully acknowledged.

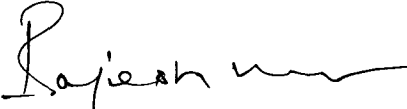
I am highly thankful to **Aeronautical Research and Development Board (AR&DB)**, Ministry of Defence, Government of India for providing funds under equipment grant. It helped me to conduct necessary experimentation.

I wish to thank **Mr. Shashi Kumar Singh**, my lab mate with whom I exchanged views and made scientific discussions. He has been always ready to extend help. I am also highly thankful to **Dr. Shashi Prakash**, my immediate senior with whom I had made scientific discussions many times. During my stay at IIT, I also got opportunity to work with many M.Tech. students starting from **Mr. Kuldeep Singh** to **Vikas Rathi** and **Vijay Raj Singh** in the same laboratory. It was really enjoyable to work with them. My sincere thanks are to them for accompanying me in the laboratory beyond the normal timings and providing help whenever required. I am also thankful for the company provided by **Ms. Madhuri Thakur**, **Ms. Priti Singh**, **Ms. Saba Mirza**, **Md. M. Hossain** and other group members. Help provided by **Ms. Priti Singh**, **Ms. Saba Mirza** and **Mr. R. B. Verma** during the final stage of preparing the thesis is duly acknowledged. My sincere thanks are to **Mrs. Chandra Shakher** who always encouraged me for an excellent research work and shared my personal problems.

Help extended by **Mr. Hoshiyar Singh** and the supporting technical staff of Laser Application and Holography Laboratory is thankfully acknowledged. I too wish to thank the staff of I. D. D. Centre and Mechanical Engineering Department for their help.

Finally, with deep sense of gratitude, I wish to thank my parents, wife and family members for their patience, understanding and moral support that remain intact in giving me the sense of purpose and devotion to realize the work.

Date: 14.04.2003.



Rajesh Kumar

# ***ABSTRACT***

## ***MEASUREMENT/ MONITORING OF VIBRATIONS USING DIGITAL SPECKLE PATTERN INTERFEROMETRY***

In the present thesis we have investigated various parameters including a filtering scheme to improve signal to noise ratio (SNR) in digital speckle pattern interferometric (DSPI) fringes. DSPI system is constructed for measurement of out-of-plane deformations/ vibrations. To make the system more robust and compatible to industrial environment, a program for recording and displaying the DSPI interferograms with high SNR has been developed. The program has the capability to take care of small rigid body displacement/ rotation of the object, the direction of illumination and low frequency fluctuations in the lighting conditions. By using newly developed filtering scheme the DSPI vibration pattern can be analyzed with better accuracy. The filtering scheme is based on average/ median filtering followed by Symlet wavelet filtering. In comparison to the Daubechies wavelet filtering scheme, the Symlet wavelet filtering is also effective at the edges of the fringes. If the number of speckles in the fringes is more, a combination of median filtering and Symlet wavelet filtering is found to be more effective. If the number of speckles in the fringes is moderate, a combination of average filtering and Symlet wavelet filtering is more effective. We have also developed a graphical program in LabVIEW environment to draw a line profile for analyzing the filtered DSPI fringes. Information about fringe spacing and the position of maxima and minima are obtained from the line profile.

In the present thesis, DSPI is applied to study the vibrations in four different objects. Vibration mode shapes were recorded for a loudspeaker diaphragm, which is analogous to a circular plate, fixed at outer edge. Further exhaustive studies were made to study vibrations in rectangular and square plates. Effects of change in excitation frequency, excitation force, stiffness and boundary conditions on the mode shape of vibration of the plates were also investigated. Using DSPI fringes amplitudes of square/ rectangular plates at different points under resonance and other dynamic deformation conditions were evaluated. By using the calculated amplitude data, the deformation maps were generated. These maps can be used to interpretate nodal lines and high deformation zones. The results were verified with the measurements using accelerometer and laser Doppler vibrometer at certain points of interest. The amplitudes measured by DSPI system, accelerometer and laser Doppler vibrometer were in good agreement. DSPI based experimental investigations reveal that the frequencies of the normal modes for transverse vibration in the structures are in general not harmonically related. Furthermore, DSPI has been applied to record the fringe patterns due to vibrations on the surfaces of a bracket of an electric motor and of a hard disk drive of a computer.

The thesis is organized in five chapters:

Chapter 1 provides a brief introduction to vibration in structures. This chapter also presents a brief description of various electro-mechanical and optical techniques for measurement of vibrations.

Chapter 2 deals with a new filtering scheme based on Symlet wavelet filtering which has been investigated and implemented to improve the SNR of DSPI fringes obtained for vibrating objects.

Chapter 3 deals with the study of out-of-plane or transverse vibrations in a square plate. In this chapter, large number of fringe patterns are shown for square plate with two different boundary conditions. Experimentally obtained resonance frequencies for the square plate for the boundary condition one edge fixed and other edges free, the resonance frequencies obtained from DSPI show good agreement with that obtained from classical theory for thin plates.

Chapter 4 deals with study of out-of-plane or transverse vibrations in rectangular plate. A large number of fringe patterns are shown for a rectangular plate with two different boundary conditions. Experimentally obtained resonance frequencies for the rectangular plate for the boundary condition one edge fixed and other edges free, the resonance frequencies obtained from DSPI show good agreement with that obtained from classical theory for thin plates.

Chapter 5 deals with the measurement/ monitoring of vibrations of a surface of computer hard disk drive.

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