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THE EXPERIMENTAL STUDY BY ELECTRONIC SPECKLE PATTERN INTERFEROMETRY OF RESONANT FREQUENCIES AND MODE SHAPES FOR SQUARE LAMINATE PLATES WITH ROUNDED CORNERS AND CHAMFERS

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ABSTRACT
Electronic speckle pattern interferometry (ESPI) was used for tuning and visualization of natural frequencies of a square laminate plate with rounded corners and chamfers. The plate was excited to resonant vibration by a sinusoidal acoustical source, which provided a continuous range of audio frequencies. Numerical calculations of resonant frequencies and mode shapes based on a finite element package are also performed and good agreements are obtained if compared with experimental measurements. The influence of shaped of corners, which include rounded corners and chamfers, on the vibration analysis of square plates is discussed in detail. It is interesting to note that the mode number sequences for some resonant modes are changed. The transition of mode shapes from the square plate to the circular plate is also discussed.
Keywords: electronic speckle pattern interferometry, mode shape, resonant frequency

1. INTRODUCTION
Transverse vibration of plates has extensive application in civil, mechanical, aerospace, and material engineering. Governing equation of a vibrating plate in the Cartesian coordinate system is first given by Sophie Germain. [1]

$$D\nabla^4 w + \rho w_{tt} = 0 \qquad (1)$$

where $w = w(x, y, t)$ is the vertical displacement and

$$D = \frac{Eh^3}{12(1-\nu^2)} \qquad (2)$$

with *D* - flexural rigidity, *E* - Young modulus, ν - Poisson ratio, *h* - half–thickness, ρ - density.

Real- time electronic speckle pattern interferometry (*ESPI*) is useful tool to carry out non-destructive tests in a variety of fields such as optical metrology, industrial process control and visual inspection line. [2, 3] The technique is well suited to measure deformations in mechanical systems subjected under several boundary conditions.

2. METHOD
The schematic layout of self-arranged ESPI optical system, as shown in Figure 1, is employed to perform the out-of-plane vibration measurement of the resonant frequencies and mode shapes for composite plates. A He-Ne laser with wavelength $\lambda = 632{,}8nm$ is used as the coherent light source. The laser beam is divided into two parts, the reference and object beans, by a beam splitter.

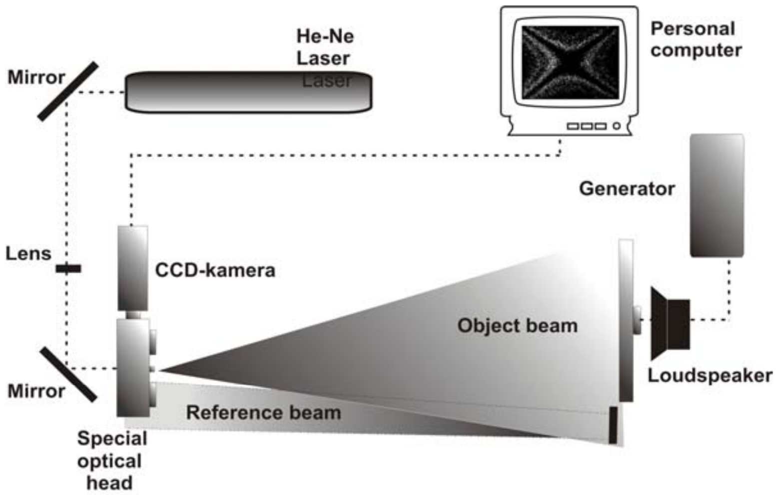

Figure 1. Schematic diagram of ESPI set-up for out – of-plane measurement

The objects beams travels to the specimen and then reflects to the CCD camera. The reference beam is directed to the CCD camera via the mirror. Note that the optical path and the light intensity of those two beams should remain identical in the experimental setup. The CCD camera converts the intensity distribution of the interference pattern of the object into a corresponding video signal at 30 frames per second. The signal is electronically processed and finally converted into an image on the video monitor. To increase the intensity of light reflection of the specimens and contrast of fringe patterns, the surfaces of the plates are coated with white paint. The plate was excited to resonant vibration by sinusoidal acoustical source, which provided a continuous range of audio frequencies. Fringe patterns produced during the time-average recording of the vibrating plate-corresponding to several resonant frequencies-were registered. [4, 5]

3. EXPERIMENTAL RESULTS AND NUMERICAL ANALYSIS

In this part, the optical method based on the ESPI is employed to study experimentally the vibration of plates with rounded corners. The boundaries conditions are along the circumferential edge are traction free and the plate is fixed in the centre. (Figure 2) The isotropic composite plates with rounded corners are used in this study for experimental investigations and numerical calculations.

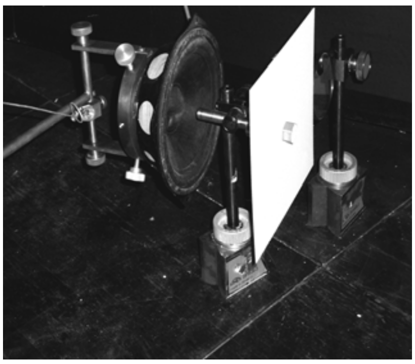

Figure 2. The fixation of the plate

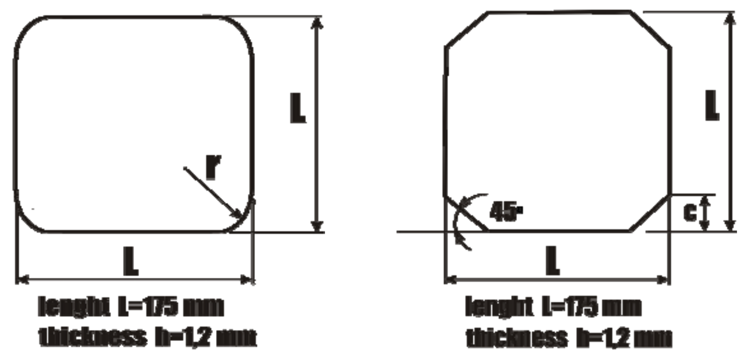

Figure 3. Geometric dimension and configuration of the (a) rounded and (b) chamfered plates

The material properties of the prepreg plates are mass density $\rho = 1600 \ kg/m^3$, Young's modulus $E = 21 \ GPa$ and the Poisson ratio $\upsilon = 0{,}13$. The geometric dimensions of the rounded plates are illustrated in Figure 3. The radius of the corner r is taken to be 10, 20, 30, 40, 50, 60, 70 and 87,5 mm in this analysis. Numerical results of resonant frequencies and mode shapes are carried out by using the commercially available software, COSMOS.

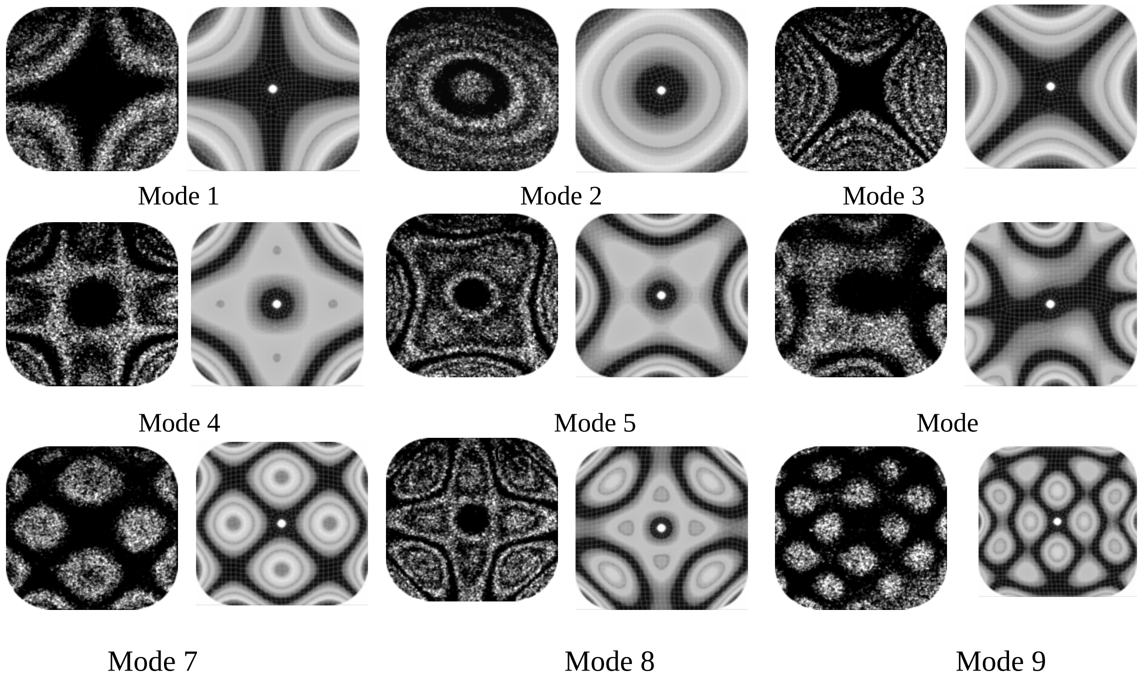

Figure 4. Mode shapes of the R – 40 plate obtained by ESPI and FEM

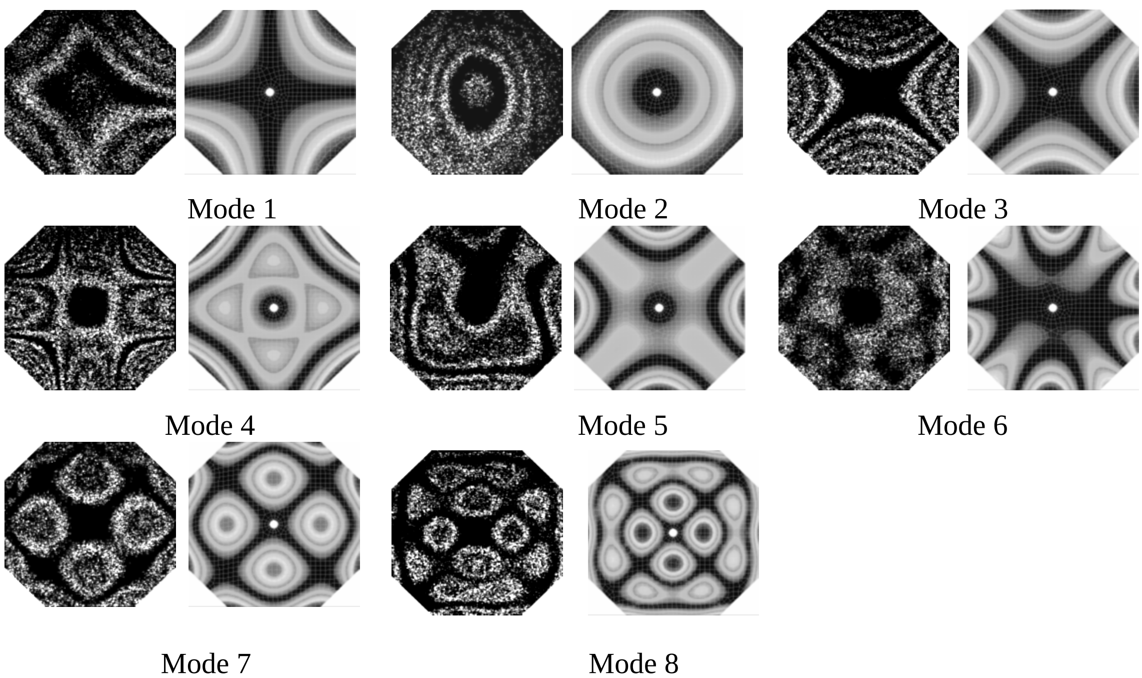

Figure 5. Mode shapes of the Cham – 40 plate obtained by ESPI and FEM

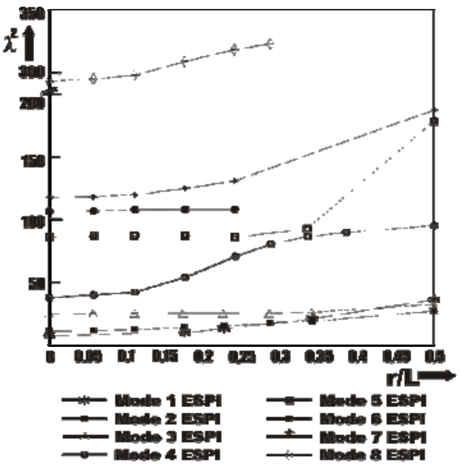

Figure 6. The results of non-dimensional frequencies for rounded plates with different radii of corners

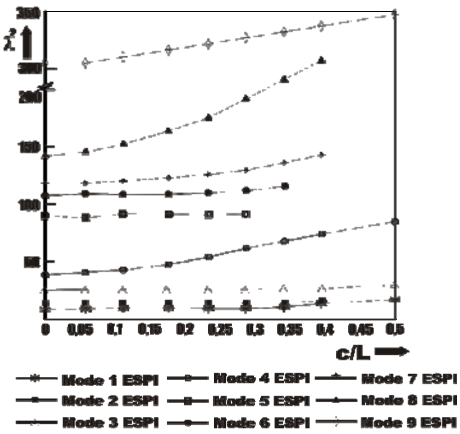

Figure 7. The results of non-dimensional frequencies for chamfered plates with different chamfer lengths

It is interesting to note that resonant frequencies of the second mode are almost constant and resonant frequency fifth mode varies drastically for the rounded plates. Note that r/L =0 represents the square plate and r/L =0,5 represents the circular plate. We find that the frequencies of the fifth mode are increasing drastically and higher than the sixth mode for r/L ≥0,20, which means, that the orders of these two modes exchange each other. It is indicated from these results that some modes of the square plate will combine to form the correspondent modes of the circular plate which are composed of only the nodal diameters and circles. Figure 7 describes the results of non-dimensional frequencies for chamfered plates with different chamfer lengths. It is shown that resonant frequencies of mode shapes 2, 3, 6 are change only minimally. It is also interesting to note that resonant frequency of mode shapes 5, 7 are change very sharply.

4. CONCLUSIONS

Compared with the spectrum analysis or modal analysis method, ESPI is more convenient in experimental operation. The influence of the shape of corners, which include rounded corners and chamfers, on the vibration analysis of square plates is discussed in detail. For the completely boundary condition, the mode shapes of a square plate with round corners are shown to transform into those of a circular plate, which are nodal diameter and nodal circles. The exchange of some modes in number for these two types of plates is observed.

5. REFERENCES

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