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실시간 진동측정시스템에 관한 연구

A Study on the Real-time Vibration Measurement System

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ABSTRACT

In this paper, real-time vibration measurement using system is described.

Modes getting from different vibrational frequencies of some vibrational plates are rectified and filtered by digitizer and recorded 480 dots (abscissa) printer. PZT and mechanical choppper is placed in front of cw laser for better resolving power.

Rayleigh's mode theory and mode pattern are compared with experimental results.

1. Introduction

The first hologram of a vibrating object was made in 1964 and it was the culmination of a series of experiments(1) that give birth to the new field of hologram interferometry.

But much time is needed in making holograms of unimportant conditions in order to fine the required results. Some workers have set out to overcome these difficulties by adaptations of real time holographic interferometry which enables chaging modes to be observed. Unfortunately, such rigs require a level of environmental stability not likely to be achieved outside the specialist laboratory.

A different approach yielding fringe information of the form given by Powell and Stetson has been developed in some others' laboratory following speckle pattern analysis by Leendertz(2).

TV detection and electronic filtering technique have been combined with the principle of speckle interferometry to give a more flexible system(3,4).

The method cannot reach the high image quality of holographic interferometry due to low resolution of the TV system. But for practical applications these disadvantages are outweighed by the high sampling rate of the TV system. A new interferogram is recorded and displayed every 1/25-1/30 second, which also gives the rather short exposure time of that period(5).

The techniques of time-lapse interferometry and contouring have limited application because the photographic processes used are not suited for inspection and nondestructive testing of mass-produced items. This is true of products such as automobile tires, loudspeaker inspection, and material checks, where the time and cost of a photographic operation for each item is prohibitive.

In this paper, using TV systems(6) not only are rapid but do not involve any expendable materials. Vibrational mode theory and making objects is dealt. Experiment using TV system and chopping method is shown, and the experimental result is considered by comparing with vibrational mode theory results.

2. Rayleigh mode theory

The classical analysis of Rayleigh about the vibrations of plates bears the same relation to the study of the membranes as the study of the vibrations of bars does to the study of the flexible string. The effect of stiffness in both cases increases the frequencies of the higher overones more than it does those of the lower overtones, and so makes the fundamental frequency very much lower than all the overtones. However, the motions of a plate are very much more complicated than those of a bar; so much more complicated that we shall have to be satisfied with the study of one example, that of the circular plate, clamped at its edge and under no tension. The diaphragn of an ordinary telephone receiver and the circular plate fixed the perimeter of a loudspeaker are plate of this type; so the study will have some practical applications.

The derivation of the wave equation for the plate involves more discussion than is worthwhile here. The equation is,

$$\nabla^4 \eta + \frac{3\rho(1-s^2)}{Q h^2}\frac{\partial^2 \eta}{\partial t^2} = 0$$

where ρ is the density of the material, s its Poisson's ratio, Q its modulus of elassticity, and h the half thickness of the plate.

3. Simple harmonic vibrations

The differential operator is difficult to separate in most coordinate systems, but for polar coordinates the results turn out to be sufficiently simple to justify analyzing them in detail. Here, if we set $\eta = Y(r,\phi)e^{-2\pi i \nu t}$, where Y's dependence on ϕ is by the factor cos or sin$(m\phi)$, then the differential equation for Y can be written,

$$(\nabla^2 - \gamma^2)(\nabla^2 + \gamma^2)Y = 0$$

$$\gamma^4 = \frac{12\pi^2 \nu^2 \rho(1-s^2)}{Q h^2}$$

Therefore Y can be a solution either of $\nabla^2 Y + \gamma^2 Y = 0$ or of $\nabla^2 Y - \gamma^2 Y = 0$.

Since ∇^2 and Y are to be expressed in polar coordinates, the solution of the first equation, which is finite $r=0$. is

$$Y = \frac{\cos}{\sin}(m\phi) J_m(\gamma r)$$

where m is an integer. This is the usual solution of the plate, with γ instead of $\frac{2\pi\nu}{c}$. The solution of the second equation is obtained from the first by changing γ into $i\gamma$, and necessitates a little discussion of Bessel functions of imaginary values define them by the equation $I_m(z) = i^m J_m(iz)$.

4. The normal modes

Possible solutions for the simple harmonic oscillations of a plate are therefore given by the expressions,

$$Y(r,\phi) = \frac{\cos}{\sin}(m\phi)[A J_m(\gamma r) + B I_m(\gamma r)]$$

The boundary conditions corresponding to a circular plate of radius a, clamped at its edges, are that $Y(a,\phi)=0$ and $(\partial Y/\partial r)_{r=a} = 0$. The first condition is satisfied by making

$$B = -A\frac{J_m(\gamma a)}{I_m(\gamma a)}$$

and the second condition is satisfied by requiring that γ have those values that make

$$I_m(\gamma a)\frac{d}{dr}J_m(\gamma r) - J_m(\gamma a)\frac{d}{dr}I_m(\gamma r) = 0 \quad \text{at } r=a$$

This equation fixes the allowed values of the frequency, for γ depends on ν Label $\gamma_{mn} = (\frac{\pi}{a})\beta_{mn}$, and where

$\beta_{01} = 1.015$,	$\beta_{02} = 2.007$,	$\beta_{03} = 3.000$,
$\beta_{11} = 1.468$,	$\beta_{12} = 2.488$,	$\beta_{13} = 3.490$,
$\beta_{21} = 1.879$,	$\beta_{22} = 2.992$,	$\beta_{23} = 4.000$,

$$\beta_{mn} \underset{n\to\infty}{\longrightarrow} n + \frac{m}{2}$$

The allowed values of the frequency are therefore

$$\nu_{mn} = \frac{\pi h}{8a^2}\sqrt{\frac{Q}{3\rho(1-s^2)}}(\beta_{mn})^2$$

$$\nu_{01} = 0.9342\frac{h}{a^2}\sqrt{\frac{Q}{\rho(1-s^2)}}$$

$f_{01} = 1.0 f_{01}$,	$f_{02} = 3.909 f_{01}$,	$f_{03} = 8.736 f_{01}$,
$f_{11} = 2.091 f_{01}$,	$f_{12} = 5.984 f_{01}$,	$f_{13} = 11.823 f_{01}$,
$f_{21} = 3.427 f_{01}$,	$f_{22} = 8.689 f_{01}$,	$f_{23} = 16.53 f_{01}$,

Table 1 Relative frequencies of a circular plate

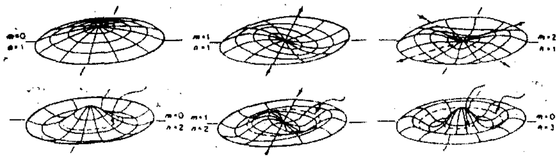

Fig.1 Shapes of a few of the normal modes of vibration of a circular plate clamped at its edge.

5. Vibrational objects

For the measurement of diffusive vibrating objects, copper and aluminium plates are chosen.

The test objects are mounted on a loudspeaker clamped at its perimeter.

6. Experiment and results

The set up for vibrating object test is below,

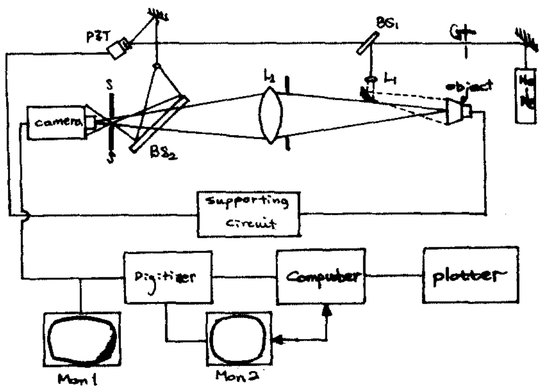

Fig. 2 ESPI set up

For regulating cw laser exposure period in connetion with vibrational frequencies, mechanical choppers are designed. The exposure length of every chopper should be confined with 1 frame rate. Spatial noise and environmental vibrational noise are reduced by stopping down SS. The TV system operating with the vidicon tube will then see speckles where bright fringes should be and no speckles where the dark fringes should be. Combining this with the scanning, the two regions are distinguishable by differing video frequencies which can be separated by filtering, and the resultant display made equivalent to the time averaged hologram.

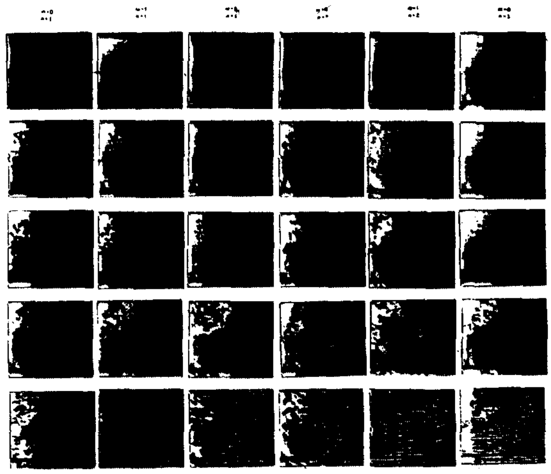

Fig. 3 Speckle patterns from ESPI set up

Mode / Material	m = 0, n = 1, f_{01} = 1.0 f_{01}	1, 1, [illegible]	2, 1, [illegible]	0, 2, [illegible]	1, 2, [illegible]	0, 3, [illegible]
0.4mm copper	603 620	1261 1350	2065 2450	2352 2890	3607 3960	5267 5880
0.3mm aluminum	621 625	1299 1320	2129 2250	2425 2550	3718 3870	5429 5630
0.4mm aluminum	828 890	1732 1825	2838 2940	3233 3370	4957 4220	7239 7650
0.4mm aluminum Texp ≈ 7 Tv	828 890	1732 1825	2838 2940	3233 3370	4957 4220	7239 7650
0.4mm aluminum Texp ≈ 60 Tv	828 890	1732 1825	2838 2940	3233 3370	4957 4220	7239 7650

Table 2 Measuring frequencies

Fringes from experiments are nearly agreed to those expected Rayleigh mode pattern.

Copper has higher than aluminum in density, Young's modulus, and Poisson's ratio. So even the fundamental frequency at copper is placed on high value. And large exposure time shows that the fringe patterns are deblurred to a large extent.

7. Conclusions

Rayleigh's mode pattern can be obtained by theoretical method. And the anticipating mode frequencies can be gotten by ESPI way. Gathered mode frequencies consists modal bank and mode correllator could be used for detecting vibrating frequencies.

Speaker inspection line and plate flatness also apply this method even randomly.

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