Proceedings of The Institute of Acoustics

A NEW TECHNIQUE OF WAVENUMBER ANALYSIS FOR THE STUDY OF STRUCTUREBORNE VIBRATION

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INTRODUCTION

Wavenumber/frequency (or k-spectrum) analysis has been available as a technique for the study of structureborne vibration for some time but is not widely used, possibly due to the practical difficulties involved in applying it. This paper presents a new method which is simple and reliable to apply, and it is suggested that it could be useful in investigations of the vibrational behaviour of a wide range of structures.

At high frequencies (in structural vibration terms) methods such as modal analysis are impossible to apply and k-spectra can provide a unique means of studying the vibrational wavefield, indicating, for example, the presence of standing waves or travelling waves, and hence possible power flow, and from a knowledge of the wavenumbers present it can be determined if the field will radiate into the surrounding fluid. The spectra can also show how the wavefield is modified by transmission through the structure, perhaps indicating how it could be controlled.

THE K-SPECTRUM

Figure 1 (a) shows at a frozen instant of time a section of a plate across which a plane sine wave is propagating. Taking a two-dimensional spatial sample of the plate motion at 20 x 20 points in a square array and performing first a frequency transform and then spatial transforms in the x and y directions produces a k-spectrum at the frequency of the wave as shown in Figure 1 (b). The effects of the spatial window can be seen as sidelobes aligned in the directions of the two spatial transforms. The spectrum is plotted in log magnitude format, covering an 80dB range. Applying a cut-off at 40dB removes the sidelobes and makes interpretation of the spectra simpler; see Figure 1 (c).

A single wave then appears as one broadened peak in the spectrum. A vector from the origin to the peak defines its wavenumber and direction, and the height of the peak its amplitude.

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THE EXPERIMENTAL METHOD

To produce a k-spectrum, it is necessary to record an array of frequency spectra from a grid of points on the test structure. The "traditional" means of doing this is to apply an array of sensors, such as accelerometers, excite the structure, and record a spectrum from each sensor. This method has a number of inherent drawbacks; firstly a large number of sensors is required, which also means complex data acquisition equipment. Perhaps more serious are problems caused by differing characteristics for each sensor and its mounting, leading to inaccuracies in the spectra and usually limiting the upper frequency of the measurements.

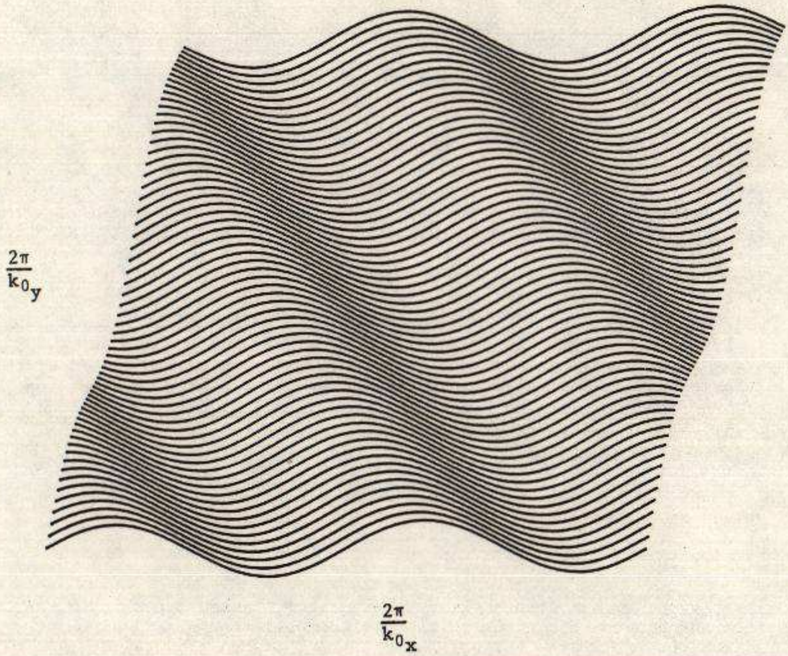
The new method eliminates these problems and makes possible measurements of good spectra with far less effort. The method invokes the principle of reciprocity, and does away with the array of sensors. Instead, an instrumented hammer is used to tap over the spatial array of points, and the output is recorded at a single accelerometer. This is exactly equivalent to exciting the structure at the position of the accelerometer and recording the response at each grid point. An array of transfer functions is thus produced with one set of measurements.

To produce a k-spectrum from the transfer functions, the complex values at any particular frequency are extracted for all the grid points and spatially transformed using the FFT facility of a frequency analyser.

This technique has been applied to a variety of structures in both one and two dimensions. As an illustration, Figure 2 shows a spectrum for a 16mm thick steel plate using a 20 x 20 array. Another interesting application has been to the study of flexural wave transmission along a periodically ribbed steel cylinder. The cylinder is 5 feet diameter and 21 feet long, with circumferential ribs every 6 inches. 2-D spectra have been produced in the individual bays and 1-D spectra measured on the ribs at frequencies up to 20kHz. Figure 3(a) shows a waterfall plot of some of the rib spectra. The resolution of the spectra have also been improved by using a maximum entropy technique as described in the preceding paper, and the improvement in the spectra can be seen in Figure 3(b). As mentioned in the first paper, the results from the measurements have proved very enlightening and compare well with theoretical models. It is hoped to be able to apply maximum entropy techniques to 2-D analysis in future.

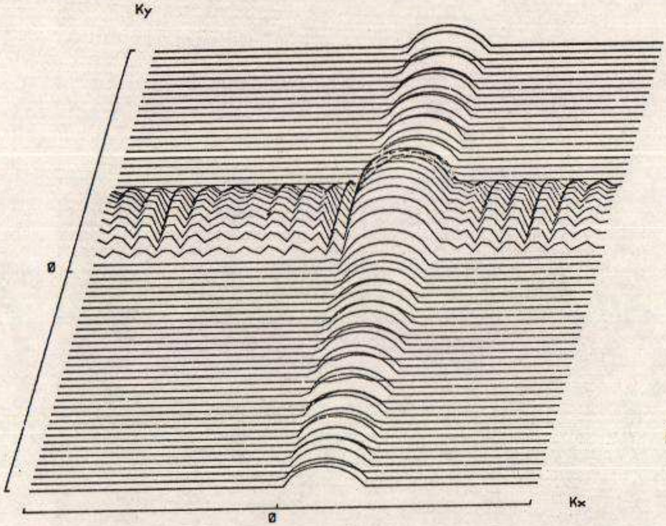
ACKNOWLEDGEMENT

The work described in this paper was sponsored by the Procurement Executive of the Ministry of Defence.

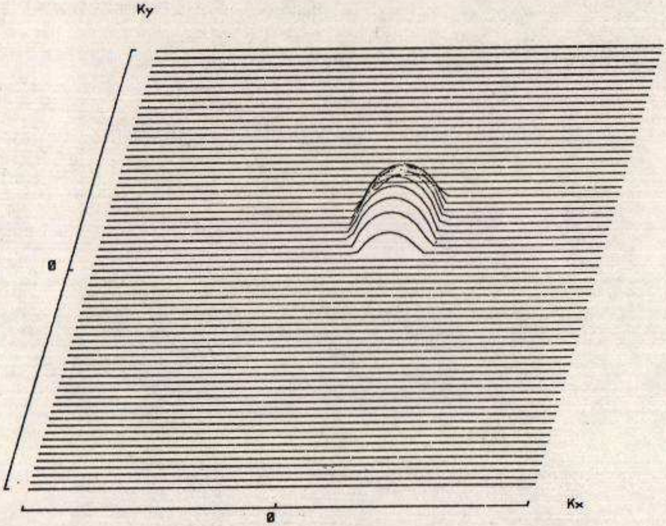


(a)

Figure 1 (a) A section of plate across which a plane sine wave is propagating towards the top right.



(b)



(c)

Figure 1 (b) k-spectrum produced using 20 x 20 samples. Vertical scale is logarithmic, covering 80dB.

(c) The same spectrum with cut-off at 40dB.

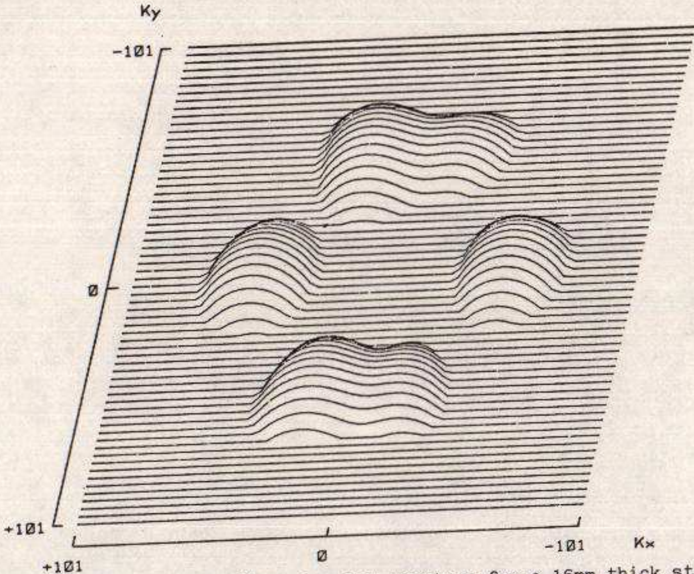


Figure 2 Two -dimensional k-spectrum for a 16mm thick steel plate at 1016Hz, using 20 x 20 points.

(a)

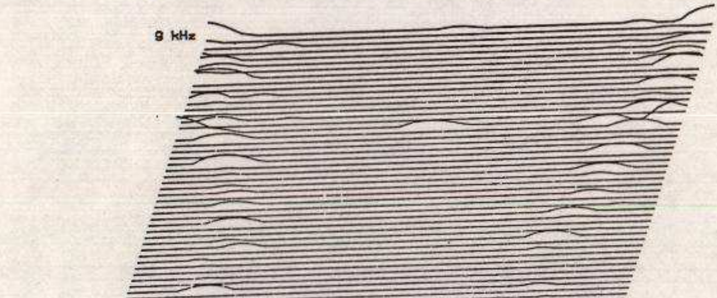


Figure 3 (a) Waterfall plot of linear wavenumber spectra versus frequency for a circumferential rib on a periodically stiffened cylinder of diameter 5 feet, using a 20 point fourier transform.

(b)

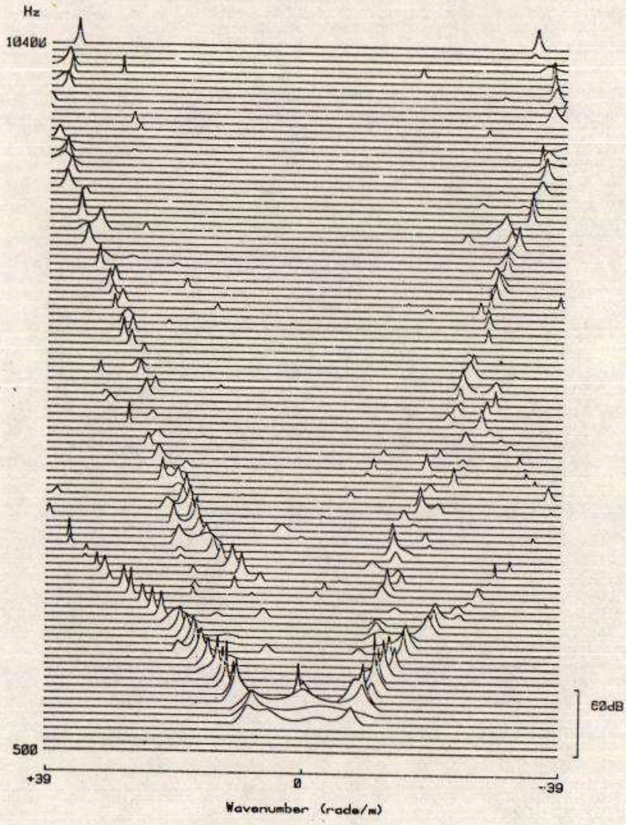


Figure 3 (b) k-spectra from the same data produced using the maximum entropy technique.