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VIBRATIONAL POWER TECHNIQUES APPLIED TO TRANSIENT WAVE MOTION IN BEAMS

P J Dixon, T J Gordon & J L Horner

Department of Aeronautical and Automotive Engineering and Transport Studies, Loughborough University, Leicestershire, LE11 3TU, UK

1. INTRODUCTION

Impacts are of importance in many engineering applications. When attempting to carry out control actions in response to impacts of a certain magnitude, it is useful to be able to characterise the resulting wave motion. If information such as the magnitude and direction of a pulse could be determined, then this could be used to make decisions about the impact. This would be especially useful, for example, in the control of active and adaptive secondary safety systems in vehicles.

In one-dimensional structures, various wave types may propagate due to an impact. When considering techniques for extracting magnitude and direction information from such pulses, it is important to distinguish between the dispersive and non-dispersive wave types. Techniques for the detection of non-dispersive pulses in the presence of signal contamination are well documented, employing methods such as correlation and applying the Bayes criterion [1].

In dispersive systems, the problem is more complicated. Attempts which have been made to apply correlation techniques to dispersive systems illustrate the problems involved [2, 3, 4]. It is, however, possible to measure the energy of a pulse, if the vibrational power is integrated over time. Cross spectral density methods for measuring energy flow have been suggested by Verheij [5] but may be unsatisfactory in rapid detection applications due to the necessary signal processing. Time domain vibrational power measurement methods such as those formulated by Pavic [6] seem to be most appropriate and are investigated here, for application to the problem of characterising an impact to an infinite beam.

2. ONE DIMENSIONAL WAVE MODEL

An infinite Euler-Bernoulli beam was modelled, with point impact excitation at the centre and a contaminating background of uncorrelated, band-limited white noise arriving from infinity in both directions. Propagating power was modelled as if it were detected at an array of velocity transducers, applying Pavic's finite difference approximation [6]. Energy dissipation in the structure, and the near-field of the background contamination were neglected.

A number of transient input models were considered. An impact by a mass, with an initial velocity at the instant of impact, may be modelled analytically by setting the force applied to the beam to be equal and opposite to the force applied to the impacting mass, and the transverse velocity of the beam to be equal to the velocity of the impacting mass, so that the mass effectively remains attached to the beam after impact [7]. An improvement of this model would incorporate a compliance between the impacting mass and the beam, and the simplest force-time history which is approximately representative of such an impact is the half-sine pulse. The theoretical Gaussian wave packet [8], which has a normally distributed frequency content also provides useful general information about the effect of bandwidth on dispersion and consequently on the integration time necessary to identify the energy of a narrow-band input.

For simplicity, attention here is restricted to half-sine inputs.

3. RESULTS

Figure 1 shows (a) the vibrational power, P and (b) the sample energy,

$$E(t) = \int_{t-T_i}^{t} P(\tau) d\tau$$

against time, t, for two measurement locations on the beam. The left half of each plot corresponds to the signal which would be acquired close to the impact location, with no dispersion of the transient, and the right half to the signal at an arbitrary remote location, allowing significant dispersion of the transient to occur.

The ribbon plots show that even with a non-optimal integration time, T_I, integration improves confidence in detecting the pulse visually. In the case of the dispersed pulse, the improvement in detection confidence between the two methods is even more significant. Although not yet demonstrated, it is expected that an improvement of a similar magnitude will occur in a practical detection application. It should however be noted that the integration time actually represents a time delay to detection.

Pulse detection at two locations for increasing contamination by random vibration: (a) Normalised Net Vibrational Power, (b) Normalised Sample Energy.

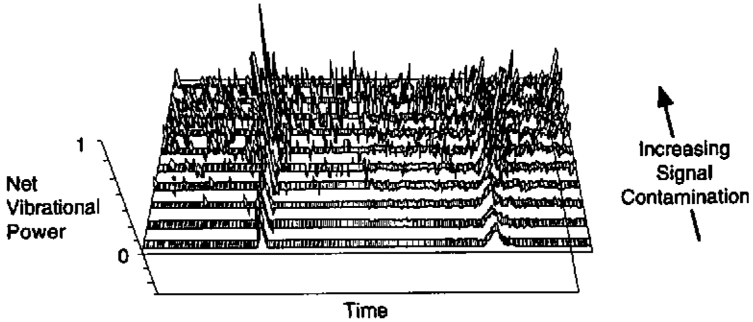

Fig. 1 (a)

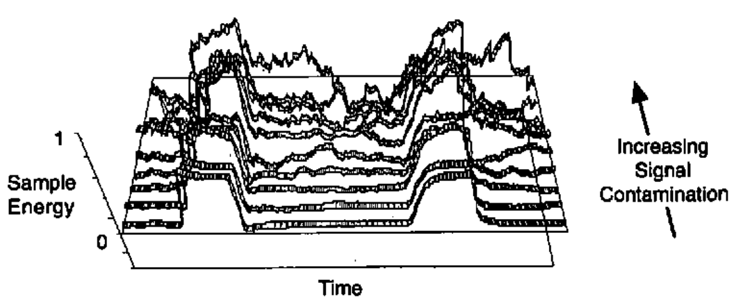

Fig. 1 (b)

4. PULSE DETECTION

As background noise increases with respect to the dispersing transient, confidence in detection decisions decreases. In a practical application, for each observation of the time-integrated energy, a choice would be made between the two hypotheses, that the signal contains a) noise only, or b) noise plus a transient. This is the subject of the statistical theory of signal detection [1], which is being employed as a formal detection criterion, to be reported in future work.

5. CONCLUDING REMARKS

This first stage investigation into the general use of vibrational power transmission for the detection of impacts in structures has been reported. Only a brief description of the detailed analytical and numerical work, involving calculation of power from travelling wave amplitudes, has been given here. Simulation results have indicated the potential benefits of applying a pulse detection criterion based on sampled energy rather than directly on vibrational power.

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