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DUAL FFT ANALYSIS APPLIED TO TESTING OF IMPACT NOISE ISOLATION OF FLOORS

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INTRODUCTION

Impact noise transmission and radiation from building structures forms an attractive field of application for the dual channel Fast Fourier Transform analysis techniques that have recently become popular in some other branches of noise control. Considerably better insight into the generation and isolation of impact noise can be obtained, when compared with the information provided by traditional measurements.

In this paper, FFT techniques are applied to the basic form of impact noise testing in laboratory, the standard tapping machine exciting a massive concrete floor slab. The frequency response and the acoustic intensity methods, as well as a new extension: the direct determination of the radiation efficiency, are made use of in investigating the transfer of energy from the input pulse to the output impact noise in Fig.1.

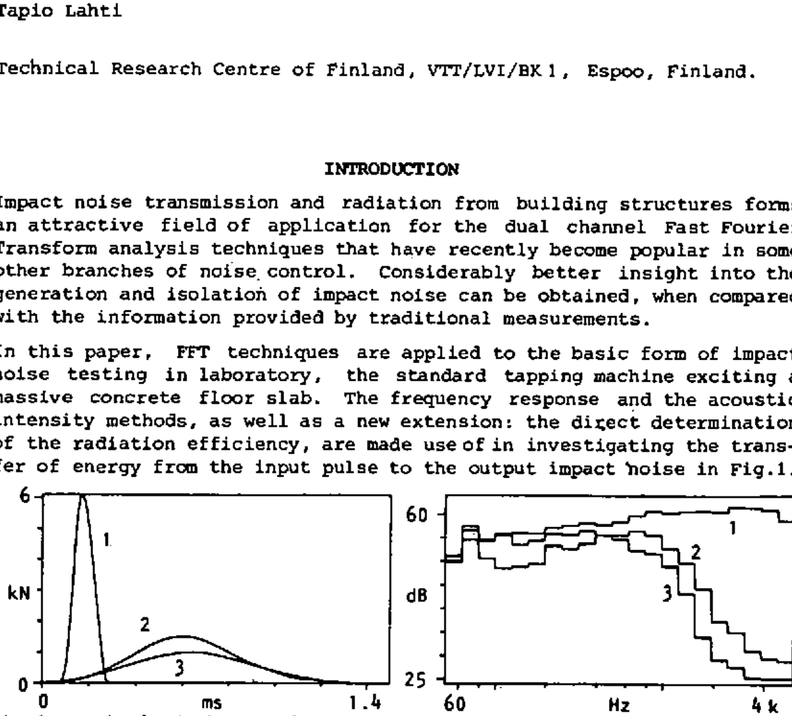

Fig.1. Typical ISO hammer force pulses and single impact energy spectra, /1/ bare and /2/ rubber hammer on concrete, /3/ bare hammer on carpet.

MODELS

Generation of hammer force

It is known [1] that a simple covering does not generally isolate impact noise, but rather it controls the generation of the input (force) signal. The production mechanism is illustrated by the equivalent circuit in Fig.2.

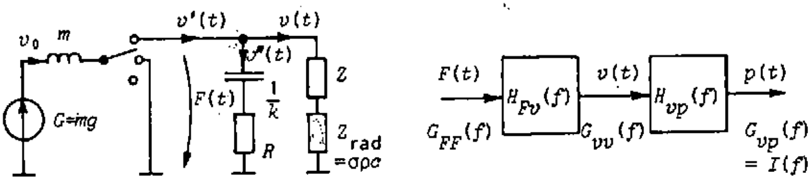

Fig.2. Linear models of (a) impact noise generation and (b) transmission of hammer force $F(t)$ to floor velocity $v(t)$ and sound intensity $I(f)$.

The velocity $v(t)$ flowing into the point impedance Z is almost always negligible so that $v' \approx v''$ and the produced force drop F across Z is not affected by the floor itself. This makes it feasible to test the impact improvement of coverings ($1/k$ & R) by merely observing F instead of the produced sound [1],[2]. The nonlinearity met in practice does not affect this conclusion. The force may be solved by the Laplace transform

$$F(s) = (Rv_0 s + kv_0)/[s^2 + (k/Z + R/m)s + k/m] \qquad (1)$$

which has a time-domain solution of the form $A e^{-ct} + B e^{-c^*t}$.

Transmission to radiated sound

The floor-and-radiation branch (implicitly spatially distributed) in Fig. 2a may, for convenience, be modelled by the two frequency response functions in Fig.2b which relate the model to practical measurements. In terms of propagated energy, the floor frequency response H_{Fv} converts the hammer force autospectrum G_{FF} to floor velocity G_{vv}, and the radiation impedance $H_{vp} = \sigma\rho c$, where σ is the radiation efficiency, further to sound pressure, or specifically to the (time-integrated) acoustic intensity I, basically given by the (energy) cross-spectrum, $I = \mathrm{Re}\{G_{vp}\}$, of velocity and pressure. The energy "transmittance" $T(f)$ from force to intensity may be written as

$$T(f) = I(f)/G_{FF}(f) = |H_{Fv}(f)|^2 \mathrm{Re}\{H_{vp}(f)\} = |H_{vp}(f)|^2 \mathrm{Re}\{\sigma\}\rho c \qquad (2)$$

TECHNIQUES

Floor point impedance and frequency response

For most situations, the 2-D wave impedance Z of the floor is not the same as H_{Fv}. The reflections from the walls return some ms after the initial contact when the hammer is back in the air. It thus sees only an infinite floor whose impedance is real at any single f. On the contrary, H_{Fv} is coloured by resonances. With FFT techniques both of these can be directly measured; Z in Fig.3a was obtained by truncating the time histories to exclude reflections, whereas H_{Fv} in Fig.3b includes these.

Radiated acoustic intensity and radiation efficiency

The new two-transducer intensity methods allow the direct measurement of radiated energy without any concern of the receiving room. Therefore, the reverberation times are not needed, and the additional approximate assumption of a diffuse field can be neglected. Also another secondary measure, the mechanical reverberation time, [1],[2], becomes unnecessary. Background noise troubles with low levels from lighter than ISO hammer will

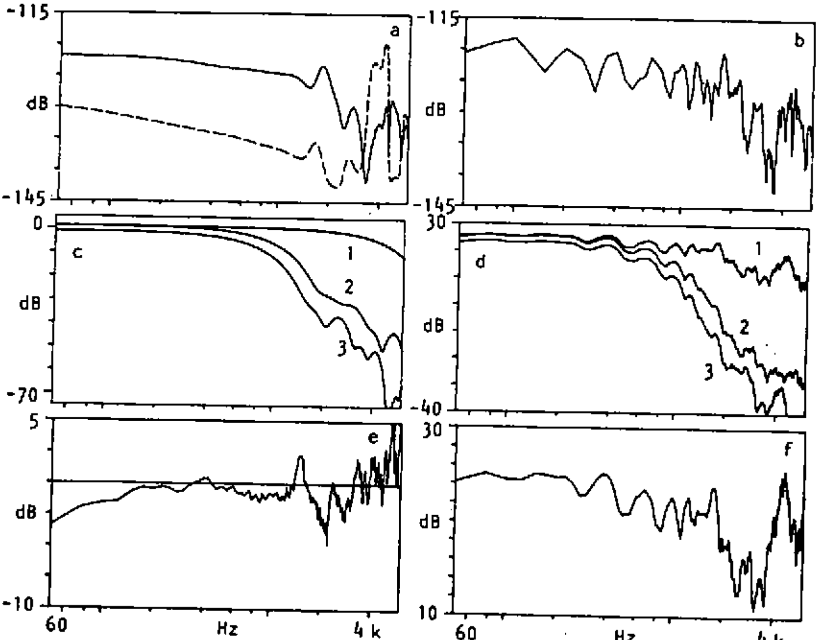

Fig.3. (a) Point admittance $1/Z$, -- phase from $-\pi/2$ to $\pi/2$, and (b) frequency response H_{Fv} of the floor; (c) force energy autospectra G_{FF} and (d) radiated acoustic intensities I of the pulses in Fig.1a; (e) radiation efficiency $\mathrm{Re}\{\sigma\}$, and (f) transmittance T, Eq.(2), of the floor.

largely be eliminated. Moreover, the radiated intensity is temporally separable from reflections yielding inherently peak-like information.

In [3] it was shown how the intensity techniques can be extended to give directly the radiation efficiency σ of a radiating surface. Basically,

$$\sigma(f) = \langle H_{vp}(f)\rangle_s/\rho c = \langle G_{vp}(f)\rangle_s/[\langle G_{vv}(f)\rangle_s\ \rho c] \tag{3}$$

where $\langle\ \rangle_s$ denote spatial averaging. Both the two-microphone acoustic and surface intensity techniques will provide the necessary signals.

ANALYSIS EXAMPLES

With the frequency response and intensity techniques, one has at hand all the necessary tools for direct measurement of energy transmission. An ISO hammer and a laboratory slab were instrumented with transducers for dual channel analysis. The input force autospectra and the output intensities for the pulses in Fig.1, together with the radiation efficiency and the ultimate goal of the analysis, the floor transmittance, are shown in Fig.3.

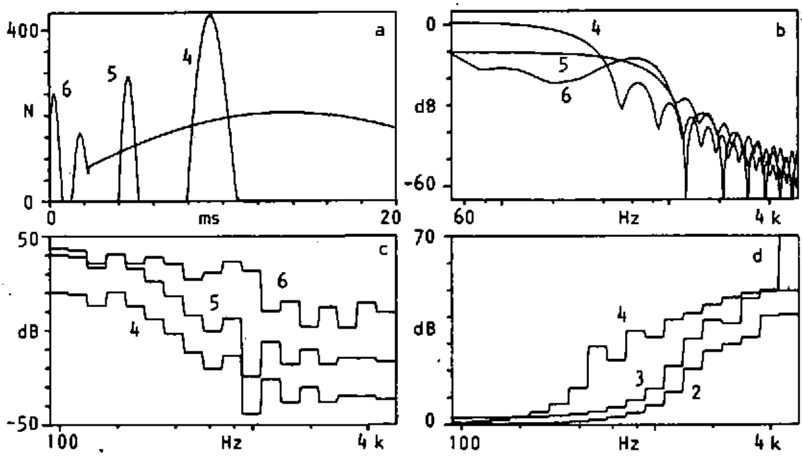

Fig.4. (a) Synthesized force of ISO hammer and a covering with $k = 6\cdot10^5$ and $R = 100$ /4/, ASTM hammer /5/, and NRC MK I Hammer /6/, [4]; (b) respective energy autospectra; (c) predicted intensities (/4/ displaced by -20 dB and /6/ by +20 dB); and (d) impact improvements for ISO pulses.

When the floor transmittance is known, any simple linear covering and any hammer can be substituted computationally using Eq.(1). In Figs.4a–c, three configurations are simulated. The autospectra of the pulses were fed to the FFT analyser to yield predictions of radiated sound from Eq.(2). Also, the impact improvements of both real and simulated coverings can be directly computed from the force autospectra, as is done in Fig.4d.

CONCLUDING REMARKS

Using the approach presented here, the primary function of interest, the radiated sound energy, becomes directly available without reference to the receiving room. Moreover, once the bare floor transmittance is determined, it suffices to measure hammer force to obtain impact noise levels. Finally, mere force measurements with and without covering give exact improvement data, and no long tapping times with ageing troubles are needed.

REFERENCES

[1] B.G. Watters, "Impact-noise characteristics of female hard-heeled foot traffic", J.Acoust.Soc.Am. 37, 619 (1965).

[2] R.D. Ford, D.C. Hothersall and A.C.C. Warnock, "The impact insulation assessment of covered concrete floors", J.Sound Vib. 33, 103 (1974).

[3] T. Lahti, "Two channel FFT analysis applied to transmission measurements", to be presented at 11th ICA, Paris 17-29 July 1983.

[4] J. Trampe Broch, "Seminar on impact sound insulation test methods", ELAB report STF44 A82022, Trondheim 1982.