inter-noise 83

ACTIVE NOISE CANCELLATION OF LOW FREQUENCY SOUND INSIDE VEHICLE CABS

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INTRODUCTION

Low frequency sound inside vehicle cabs, in particular heavy vehicle cabs, has long been recognized as a nuisance to the driver/passenger of the vehicle. Conventional techniques using sound absorption materials have shown poor results below 200 Hz, and it is in this perspective the active cancellation technique can prove itself as a suitable tool for reducing low frequency cab noise.
A feasibility study on one particular vehicle (a Renault van) has been carried out to see if the active cancellation technique is a suitable approach /1/.

CAB NOISE

Several sources are responsible for the noise in the cab, the most predominant comes from the power unit (engine, exhaust, cooling fan, inlet). The low frequency components in the noise spectrum are strongly dependent on the engine speed, see fig. 1. And since the wavelength of these frequencies is very long compared with the dimensions of the cab, one can assume that the sound field is nearly constant inside the cab. This reduces the complexity of the problem.

CANCELLATION TECHNIQUE

The main task of the project was to reduce the high noise level of the fundamental firing frequency at idle engine speed (fig. 1). The first step was to establish the most suitable control system to use for active cancellation, by studying the transfer function from the engine compartment to the cab. Because of the periodicity of the cab/engine noise signal, an adaptive noise cancellation technique would be a very feasible strategy. However, with limited time avail-

able for the project, a conventional feedback control system was chosen.
Measurements were carried out of the open-loop transfer function between a 18" loudspeaker behind the drivers head and a microphone in the cab, 30 cm from the loudspeaker. Microphone B in fig. 2. This transfer function, where the magnitude describes possible attenuation in dB and the phase the time delay in the feedback system, was the fundament for the design of the compensating network in the feedback loop. This network was realized as a transversal filter by using a Bucket Brigade Device as a tapped analoge delay (TAD-32). Its main feature is that a desired impulse response can be synthesised by changing the values of the 32 taps (weighting coefficients). A limiting factor was that only one TAD-32 filter was available (they can be cascade coupled). This would influence the frequency band of active attenuation and the stability control. A more optimal approach would be to use digital filtering.

ACTIVE ATTENUATION

With the optimal filter setting, the resulting open-loop transfer function was as shown in fig. 3. The active noise attenuation was then measured with idling engine speed. The fundamental firing frequency (30 Hz) was reduced from 101,5 dB(lin) to 85,8 dB(lin), a reduction of 15,7 dB, see fig. 4, a fairly good result at this low frequency.
But the system did not give broadband cancellation. At some higher frequencies (fig. 4) the level increased, thus indicating that the cancellation signal is in-phase with the cab noise. But, with improvements of the filtering technique, the system will give considerable cancellation from 20 to about 200 Hz as fig. 3 indicates.

At 30 Hz the cancellation zone was large enough to cover both the driver and passenger seat. The main problem with the feedback system was the lack of stability when a change in the system conditions occured.

Design criteria for the loudspeaker were also investigated and the volume velocity, not acoustical power, is the main criterion for the "anti-noise" loudspeaker.

REFERENCE

/1/. T. Berge. A feasibility study of active noise cancellation of low frequency sound inside vehicle cabs.
ELAB Report STF44 A82033, April 1982.

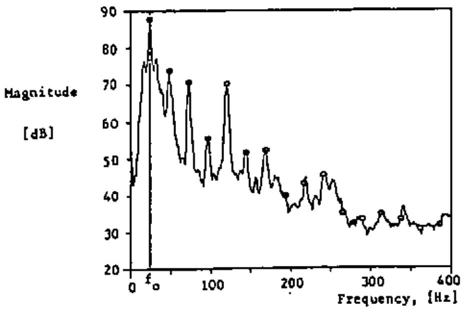


Fig. 1. Harmonics of the Fundamental Firing Frequency, f_o, at Idle Speed. Measurements inside the Cab.

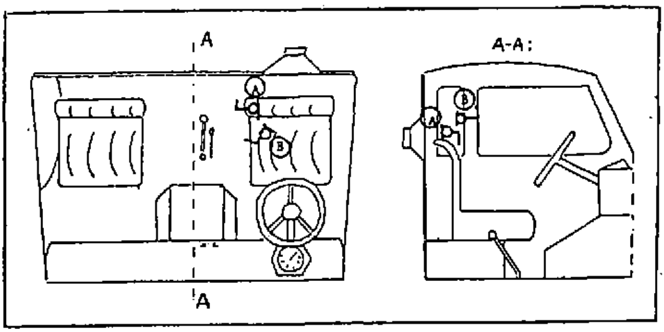


Fig. 2. Measurements of Active Attenuation.
Microphone A: Measurement of noise reduction.
Microphone B: Picking up signal for feedback loop.

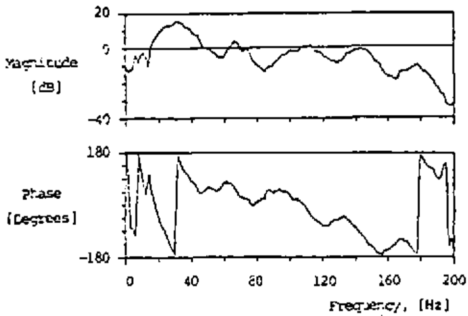
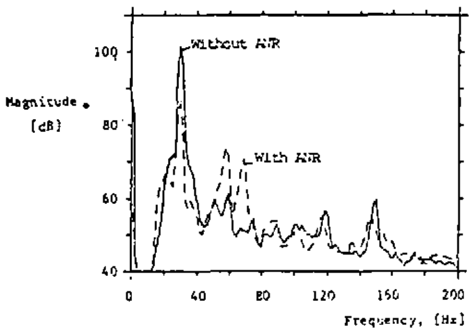


Fig. 3. Resulting open-loop transfer function.



Without ANR : Power = 105,5 dB, L_{Pmax} = 101,5 dB at f = 29,7 Hz
With ANR : Power = 91,1 dB, L_{Pmax} = 85,8 dB at f = 29,7 Hz

Fig. 4. Active Noise Reduction of the Fundamental Firing Frequency. Inside the Vehicle Cab.