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EFFECTIVE NOISE REDUCTION WITH HYBRID SILENCERS

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1. PRESENT SITUATION

The attenuation of low frequency noise by means of passive silencers can only be achieved with a high expenditure in material and volume. On the other hand active systems provide good possibilities to influence the sound field especially in this frequency range. In contrast to the well known principle of cancelling noise by destructive interference of phase shifted pressure waves (anti-noise) hybrid silencers represent a new technique of active silencing in ducts. This refers to the working principle as well as to the simplicity of the system which goes without costly and complex digital signal processing.

2. SYSTEM STRUCTURE AND EFFECTIVENESS

Hybrid silencers consist of single cassettes which contain active (speaker, microphone, analogue signal processing) and passive (porous absorber) elements (**Fig. 1**). In a compact casing (overall volume 12 litres) the passive absorber and the active system elements are covered by a perforated sheet metal and glass fibre fabrique. The microphone is located directly in front of the centre of the speakers membrane. The active system builds up a control loop where the measured microphone voltage is filtered, amplified, and fed back to the loudspeaker. The transfer function of the microphone is taken as frequency independent whereas the speaker (membrane mass, coil spring etc.) together with the rear volume of the box form in a first approximation an acoustic serial resonator. Even without any active amplification (e.g. supply voltage turned off) the increased wall compliance near the resonance frequency leads to an insertion loss typical for reactive silencers. On this basis the microphone voltage proportional to the sound pressure is inverted and fed back highly amplified to the speaker thereby forcing the membrane to react even further. Hereby the pressure in the rear volume increases whereas the pressure on the surface between duct and silencer wall decreases followed by a strong rise of insertion loss. Using the pressure in front of the membrane to generate an appropriate velocity consequently optimises the wall impedance to a value which yields a maximum of sound attenuation [1]. From an energy point of view this process is determined mainly by the transform of acoustical energy of the sound field and electrical energy supplied by the amplifier into heat caused by mechanical friction and electrical losses inside the speaker coil. Nevertheless, the electrical energy supplied by the amplifier which depends strongly on the absolute sound power level inside the duct remains rather modest even for extraordinarily high pressure fluctuations. So it was found for a single cassette amplifier the electrical power needed to attenuate an average noise level of 125 dB by approximately 10 dB did not exceed 10 watts.

3. CALCULATED AND MEASURED INSERTION LOSS

The calculation of the insertion loss IL of hybrid silencers built up of several cassettes is based upon its wall impedance. This typical measure is calculated from a complex network model including all material, electrical, and geometric data of the single elements such as loudspeaker, microphone, amplification rate, and rear box volume. The insertion loss then results from the interaction between duct and wall impedance according to [2]. The whole rather extensive calculation was coded in a PC-based program. This allows on one hand the variety of system parameters to be altered easily to give an estimation of the system performance prior to its production. On the other hand it is possible by means of the variable parameters to customise every configuration according to the requirements of any special application.
To compare the theoretical model with experimental results a silencer of 1 m in length consisting of 4 cassettes was built up on a test duct (length : 7.5 m; cross section : 0.25 m x 0.25 m). The measurement of the insertion loss was performed according to the relevant standard [3]. A non-reflecting source on the left end of the duct provided a white noise derived from a signal generator. In **Fig. 2** there is shown the comparison of the calculated and measured IL. As intended the main attenuation range is between 63 and 200 Hz. At about 100 Hz a peak level of nearly 40 dB was attained. From 250 Hz on only the 4 cm thick passive absorber layer opposite the hybrid cassettes acts as an attenuator. This layer was introduced to counteract the reflections from the wall which lower the stability of the active feedback system. Above 1000 Hz the insertion loss drops because of the acoustic beaming through the free cross section in front of the loudspeakers splitter spacing. Although some small discrepancies to the predicted values especially in the maximum and the falling part of the attenuation curve can still be observed it is demonstrated that the theoretical assumptions made compare favourably with the practical results. Both the measured as well as the predicted insertion loss

indicate cleanly the potential and effectiveness of the hybrid silencer principle.

4. REFLECTION LOSS

The insertion loss IL consists partly of propagation loss PL and reflection loss RL. A continuous pressure loss along the silencer length leads to the propagation loss whereas the reflection loss is attained by an impedance mismatch at the entrance to the silencer.

Generally the known conventional active noise control systems following the interference principle deliberately produce a wave with the same amplitude but opposite phase. At the entrance point of the silencer this anti-noise creates an almost entire reflection. Therefore the insertion loss of this type of silencer can be interpreted completely as reflection loss. If now the noise source too shows a high reflection factor consequently the mutual reflections of the sound waves lead to a higher sound pressure level between noise source and silencer (upstream). The silencer then has to attenuate this increased sound level which if at all possible lowers their efficiency [4]. By contrast, hybrid silencers because of their different working principle cause only weak reflections as was demonstrated by the measurement of the reflection loss in **Fig. 3**. As an example the behaviour of the deactivated hybrid silencer is also plotted. It can be seen that the passive system causes some reflection around the resonance frequency which rises to a maximum of 3 dB if the amplifier is switched on. However, since the insertion loss of this configuration was nearly 40 dB the remain propagation loss of 37 dB outweighs significantly the reflection loss caused by the impedance difference at the entrance of the hybrid silencer. Therefore, as an important advantage, hybrid silencers avoid the upstream increase of sound pressure level and can attenuate the unwanted noise more effectively.

5. CONCLUSION

The use of hybrid silencers in ducts represents an effective alternative to existing passive, reactive and also to conventional active noise control concepts. The compact construction guarantees modest installation costs and supports different configurations depending on the needs of the customer and the application requirements e.g. in splitter silencers.

6. REFERENCES

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[3] DIN EN ISO No. 7235: Acoustics - Measurement procedures for ducted silencers

[4] Winkler, J.; Elliott, S. J.: Adaptive Control of Broadband Sound in Ducts Using a Pair of Loudspeakers. Acustica 81 (1995), H. 5, p. 475-488.

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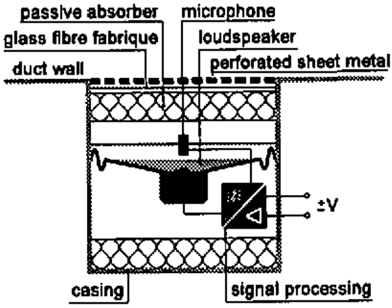

Fig. 1: Construction of a hybrid silencer cassette (HSC)

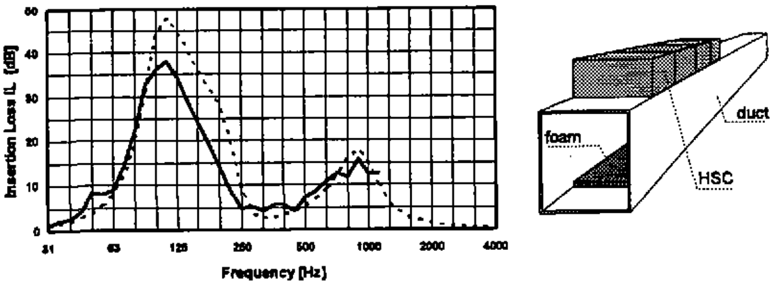

Fig. 2: Insertion Loss IL of a silencer consisting of 4 HSC with linear feedback (solid line - measured; dashed line - calculated)

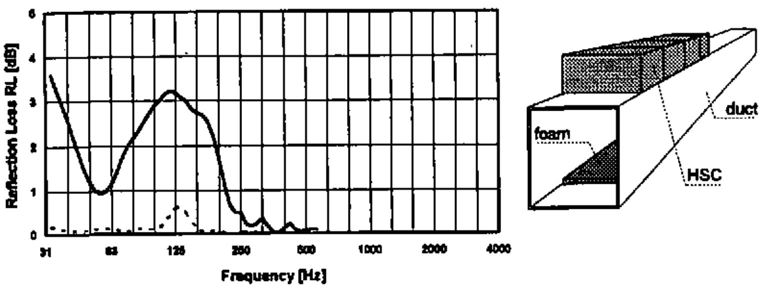

Fig. 3: Measured reflection loss RL of a silencer consisting of 4 HSC with linear feedback (solid line - HSC with feedback; dashed line - HSC without feedback)