inter•noise
83

DETERMINATION OF SOUND POWER OF SOUND SOURCES UNDER IN SITU CONDITIONS USING INTENSITY METHOD - FIELD OF APPLICATION, SUPPRESSION OF PARASITIC NOISE, REFLECTION EFFECT

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INTRODUCTION

Under "in situ" conditions especially in cases of acoustically worst environments the determination of the sound power radiated by machines renders several difficulties if the classical p^2-measurement method /1/ is used. Particularly for larger machines operating in "semi-reverberant" rooms or operating in the vicinity of other noisy machines or equipment, the measurement procedures as described in ISO 3744 and ISO 3746 /1/ frequently are applicable only with very great effort respectively with greater expense or the requirements of these International Standards cannot be fulfilled in respect to low background levels and/or to smaller environmental correction factors K_2. Therefore the recent development of the sound intensity instrumentation and measurement method is of greater practical interest, since first relevant investigations /2//3//4//5/ give the impression of a new chance to solve a greater part of these practical problems.

From a purely scientific point of view it is obvious that the new method removes all the sound power determination problems caused by the (1) near field error, (2) background noise and/or (3) undesired environmental influences c o m p l e t e l y. But from a practical point of view the following questions still remains open:

A: What are the l i m i t s of the I-method expressed in relevant measurements parameters, respectively: what is its field of applications in practice?

B: What are the requirements for a measurement procedure for the sound power determination of a machine using the I-method?

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x) Mr. D. Fischer organized the computeral evaluations (details see /6/) of the great lot of experimental data and Miss E. Klapdor assisted at the measurements.

In respect to the near field error Hübner /3//4//5/ recently showed that for usual technical sound sources such as machine the near field error occuring in practice for ISO 3744 measurements /1/ remains with high probability below 2 dB(A), if the frequency range of interest remains $\geq$ 100 Hz and the measurement distance remains $\geq$ 1 m and an isolated acoustical center have no greater eccentric location relative to the measurement surface than 0.9 (Details see /3/).

Consequently the reduction of the near field error alone do not requires a general use of the intensity meter. The method can be recommended in respect to this specific error only for "extreme cases" not falling into the frame of the measurement parameters given above. Therefore it seems relatively sure that the main field of application of the I-method will be the reduction of undesired environmental influences, called here "parasitic-noises", which covers both background noise produced by other sound sources and noise components caused by environmental reflections. In continuation the earlier research /3//4//5/ therefore this paper deals mainly with the attemps to give some answers to questions A and B especially for cases in which the sound power levels of machines shall be determined in the presence of high parasitic noise levels.

EFFECTS FOR PARASITIC NOISE SUPPRESSION AND THEIR TESTS IN PRACTICE

Under in situ conditions the sound pressure p_{Σ} and the sound velocity component $v_{n,\Sigma}$ perpendicular to a given measurement surface are composed by a term $(p; v_n)$ caused by the machine under test and $(p_{par}; v_{n,par})$ effected by the undesired environmental influences:

$$p_{\Sigma} = p + p_{par} \qquad v_{n,\Sigma} = v_n + v_{n,par} \tag{1}$$

Therefore the resulting sound intensity is expressed by:

$$I_n = \overline{p_{\Sigma}(t) \cdot v_{n,\Sigma}(t)}^t = \overline{pv_n}^t + \overline{p_{par} \cdot v_{n,par}}^t + \overline{p_{par} \cdot v_n}^t + \overline{pv_{n,par}}^t \tag{2}$$

If

$$\overline{p_{par} \cdot v_n}^t = \overline{pv_{n,par}}^t = 0 \quad \text{follows:} \tag{3}$$

$$\boxed{I_n = I_n + I_{n,par}} \tag{4}$$

with I_n = sound intensity component $\perp$ to the measurement surface and caused by the machine under test only and $I_{n,par}$ = corresponding quantity but caused by all environmental effects.

The condition Eq.(3) means that no correlation between machine noise and environmentally effected noise respectively no interaction between both components exists. This assumption can be made for measurement surfaces located in such regions of the sound field far away from reflecting planes (for monopole sources: $d_o > \lambda/_2$, details see /7/) and if significant structure borne noise propagation from the machine to elements outside the measurement surface can be excluded.

The determination of sound power of a machine under in situ condition according the method of enveloping surface

$$\oint\!\!\oint_S I_{n,\Sigma} \cdot dS \longrightarrow P = \oint\!\!\oint_S I_n \cdot dS \tag{5}$$

together with Eq.(4) requires

$$\boxed{\oint\!\!\oint_S I_{n,par} \cdot dS = 0} \tag{6}$$

which can be fulfilled either if at each single measurement position

$$\boxed{I_{n,par} = 0} \tag{7}$$

(≙local parasitic sound suppression) or/and by the integrating effect according Eq.(6).

The integrating effect

For any measurement surface S enveloping the machine under test and having no additional sound absorption inside S the Eq.(6) follows directly from the law of energy conservation and therefore is fulfilled exactly from a theoretical point of view.

If measuring $I_{n,\Sigma}$ along S one position after the other and if during the measurement duration the parasitic noises vary significantly in time the averaging time must be chosen adequately. Although such variations of noises are not excludes using Eq.(6) practical complications together with time and effort saving aspects recommend for such noises in several cases the application of the local suppression effects (Eq.(7)).

For a practical test of the integrating effect the value

$$\Delta^{*} = 10 \lg \frac{\overline{p^2}^{S}}{p_o^2} - 10 \lg \frac{\overline{I}^{S}}{I_o} = \overline{L}_p - \overline{L}_I = \text{level of parasitic noise suppression} \tag{8}$$

was determined for a sound source located outside the measurement surface and - as a first step - stationary in time and situated in a semi-anechoic room: "Zero Test". Variations of the following parameters are of interest: Microphone array including its location and number per m^2; averaging time; size and shape of measurement surface; distance of the two microphones; character of parasitic noise source (aerodynamic,.. random, pure tones,..); I-instrumentation. Results issued in /5/,/6/ show integrating suppression effects in the order of 15 dB can be realized.

The local effect (1): diffuse field component

In usual machinery halls and machinery test fields one component of the parasitic noise is more or less diffuse in character. This character in general is caused both by reverberant effects and by randomly distributed parasitic noise sources (multi-source noise radiation).
The effectiveness of the I-method to suppress diffuse field components of parasitic noise (Eq.(7)) was checked by adequate tests varying several measurement parameters. Relevant results were recently published (see /5//6/). Accordingly suppressions in the order of 10 dB up to 15 dB can be realized by present day technique.

The local effect (2): machine outer surface reflection, "nearest field" measurements

The reduction of the near field errors by using I-method opens the door to measure very close to the outer-surface of a machine ("nearest field" measurement). Most of these outer-surfaces are rigid in an acoustical sense, means for parasitic noises $v_{n,par} = 0$ (see Fig.1) respectively $I_{n,par} = 0$ as described by Eq.(7) for local suppression effects. Therefore such "nearest field" measurement can be suggested to suppress incident parasiticnoises as far as the outer surface of a machine can be regarded totally or overwhelming as a reflector for sound. A very small selection of results yielded by several tests of such a nearest field parasitic noise suppression is given by figures 2...4.

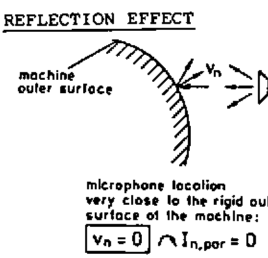
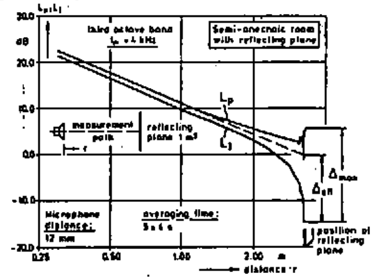
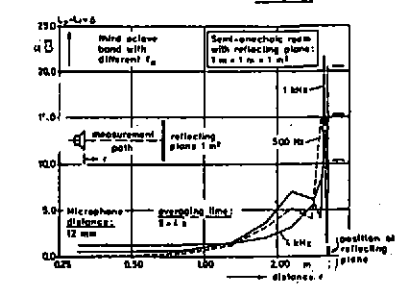


Fig.1



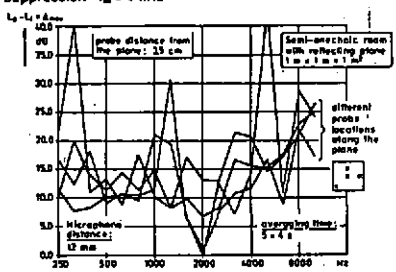
Local "reflection effect" Δ of parasitic noise suppression f_m = 4 kHz

Fig.2



Local "reflection effect" Δ of parasitic noise suppression for different distances r

Fig.3



Local "reflection effect" Δ_{max} of parasitic noise suppression, nearest field measurement

Fig.4

REFERENCES

/1/ International Standard 3744:Acoustics, Determination of sound power levels of noise sources - Engineering methods..; ISO 3746:..; Survey method. /2/S.J.Elliot, Inter Noise 81 Proceedings, 899-902./3/G.Hübner, Proceedings:Recent developments in acoustic intensity measurment,CETIM, Senlis, 1981, page 171-178./4/G.Hübner, Inter Noise 82 Proceedings San Francisco 1982, 691-694. /5/G.Hübner, DAGA/FASE Proceedings,Göttingen 1982, 427-430. /6/G.Hübner und D.Fischer,VDI-Berichtsband Nr. 468, Düsseldorf 1983, 17-24./7/G.Hübner,DAGA/FASE Proceed.Göttingen 82,p.423