inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 4.1

CHARACTERISATION OF STRUCTURE-BORNE NOISE EMITTED BY SMALL COMBUSTION ENGINES POWERING LAWNMOWERS AND OTHER GARDEN EQUIPMENTS

M. Bockhoff, P. Thoquenne, J. Tourret

CETIM, BP 80067, 60304, Senlis Cedex, France

Tel.: +33 3 4467 3346 / Fax: +33 3 4467 3617 / Email: michael.bockhoff@cetim.fr

Keywords:
STRUCTURE BORNE NOISE, COMBUSTION ENGINE, LAWNMOWER, STANDARDISATION

ABSTRACT
Low noise design of machinery needs acoustic knowledge about the involved components and their behaviour as sources of airborne and structure-borne sounds. In addition, information about links between components and receiving structure must be available in terms of transfer functions. The airborne sound emission of a component is generally characterized by its sound power spectrum which can be determined according to ISO standards of series 3740 (based on pressure measurements) or 9614 (using intensity techniques). For structure-borne sound emission very little experience is available and standards are much less proved. Based on the so called 'reception plate method', already used for the characterisation of structure-borne noise of small components, such as pumps, fans, water appliances, a measurement procedure has been developed which fits to the particular conditions of combustion engines used in garden equipments. The structure-borne noise of the engine is characterised by the airborne sound power emitted from the reception structure to which the engines is connected. Systematic measurements have been carried out on several combustion engines (power<=5 kW) mounted on different kinds of lawnmower housing. For these measurements a test rig has been used which simulates real loading conditions at various speeds. The aim of this study is: (i) To analyse the influence of different parameters on the structure-borne sound emission: running conditions, reception structure (size, shape, material); (ii) To compare the structure-borne and airborne sound emission. The experiments will be presented in the paper and discussed with respect to problems of systematic data collection for components and building of date bases needed by designers.

1 - INTRODUCTION
Low noise design of machinery needs acoustic knowledge about the involved components and their behaviour as sources of airborne and structure-borne sound. In addition, information about links between components and receiving structure must be available in terms of transfer functions. The airborne sound emission of a component is generally characterised by its sound power spectrum that can be determined according to ISO standards of series 3740 (based on pressure measurements) or 9614 (using intensity techniques). For structure-borne sound emission very little experience is available and standards are much less proved.
During the last years characterisation of structure-borne noise has been experienced by using the so-called "reception plate method", described in ISO/TC 43/WG 22/N98 [1]. Fairly suitable for measurements on small and compact components such as electric drives for car equipment, small fans used in computer devices, etc, this method is less convenient for bigger sources which

- are connected rigidly to other structures,
- generate / transmit mechanical torque,
- need a precise positioning.

First reported [2] systematic experiences have been gained on small combustion engines with horizontal axes. The relevant parameter for the structure-borne noise in that work was the space averaged vibration velocity level obtained from measurements made with small accelerometers at different points on the (perforated) reception plate of approximately 1 m^2 and thickness 2 mm. The results had shown that ranking of different engines under various running conditions might be very different when using structure-borne sound rather than airborne sound levels.
New investigations have been made with combustion engines of similar size (power < 5 kW) but with vertical axes such as used on lawnmowers.
The reception structure is no longer a rectangular, plane plate but a true lawnmower housing which allows real mounting and loading conditions for the engine. The measurement technique has been changed too: the structure-borne sound of the engine is now characterised by the airborne sound power emitted from the reception structure. Systematic measurements have been carried out on 4 engines mounted on different housings. A special test-rig has been used for this work which allows to control running conditions of the engine under test.
The aim is to compare structure-borne and airborne sound emissions and to analyse the influence of relevant parameters. Results of these investigations are presented and discussed with respect to applications in low noise design of machinery.

2 - TEST SET-UP AND NOISE MEASUREMENTS

The principal component of the test-rig is an eddy current brake that allows simulating variable loads at different speeds without additional noise. The housings used as reception structures were taken from commercially available lawnmowers of cutting width 48 cm. Figure 1 shows how the engine and the reception structure are mounted on the test-rig.

(a): Engine. **(b):** Engine+housing.

Figure 1: Views of the test-rig.

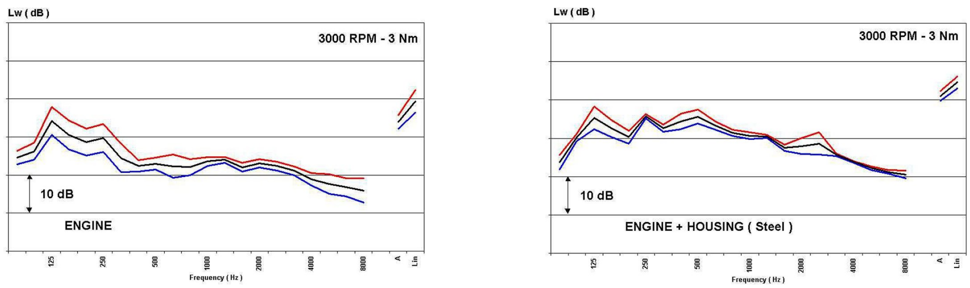
The reception structure is bolted to the test-rig by means of corner plates in the place of the wheels. This provides a rather high stiffness to the assembly and therefore may modify the radiation behaviour, especially of the housing.
On both configurations −engine only and engine with housing- the same boxlike measurement surface is used. For each test configuration sound intensities are measured by scanning 3 times on 10 segments and sound power is determined according to ISO 9614-2 [3].
The basic running condition for the engines is 3 Nm at 3000 RPM that is commonly met in a normally operating lawnmower. Structure-borne sound of the engine is defined in this work as the difference of sound powers determined with and without the reception structure:

$$L_{W,Housing} = L_{W,Housing+Engine} - L_{W,Engine} \quad (1)$$

This represents the sound that is generated by engine vibrations and radiated by the connected housing.

3 - RESULTS

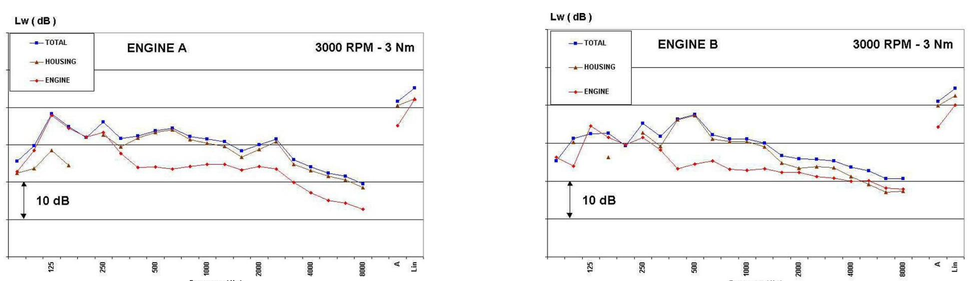
The results of a first series of measurements made on engines from different manufacturers are fairly surprising. Figure 2 shows that the airborne noise spectra have very similar shapes and that global levels have only moderate scatter.



(a): Envelope. **(b):** Mean.

Figure 2: 1/3 octave sound power spectra.

When the engines are connected to steel housing the total sound power increases by approximately 4-8 dBA. Complementary measurements have been made in order to check this response on real lawnmowers. When using a technique of partial masks, covering all unwanted sources of the complete machine, the observed increase was a little bit weaker than on the test-rig. Nevertheless, this fact of increasing sound power is of great importance for the designer since it reveals the predominance of structure-borne contributions to the global noise. In addition it appears that the ranking order of different engines changes when structure-borne noise is considered instead of airborne noise. For two engines (A and B) the individual contributions are plotted in Figure 3. They show very different trends in spectra despite similar overall levels. Structure-borne noise is dominant from 500 Hz upwards, especially in the range 500-2000 Hz where the levels are 5-10 dB higher than airborne noise levels. At lower frequencies airborne (exhaust) noise is the main contribution. It is seen that structure-borne noise cannot be inferred from airborne noise by a simple scale factor.



(a): Structure-borne. **(b):** Airborne.

Figure 3: Contributions to total sound power.

For a given engine the "amplification" by the reception structure depends of course on running conditions. In Figure 4 it is seen that with increasing speed airborne and structure-borne contributions tend to be more balanced.

Reception structures of similar shape but of different materials have been tested (steel, aluminum, plastic). Figure 5 shows the structure-borne noise generated by engine B mounted on steel and plastic housings. Significant differences appear only in particular frequency bands below 1000 Hz, probably due to different modal responses of the reception structures; the overall behaviour remains very similar. This means that the choice of the material is important if the frequency dependent behaviour is needed, it seems to be less critical if only a rough global ranking is wanted.

4 - CONCLUDING REMARKS

Measurements have shown that the combustion engine is one of the main noise sources of lawnmowers. The designer of such equipment who has to face more and more stringent regulations may be interested in databases allowing to optimise the choice and the integration of components.

Previously reported work has already shown that such databases have to include -besides airborne sound emission data- information about structure-borne sound as function of both, frequency and running

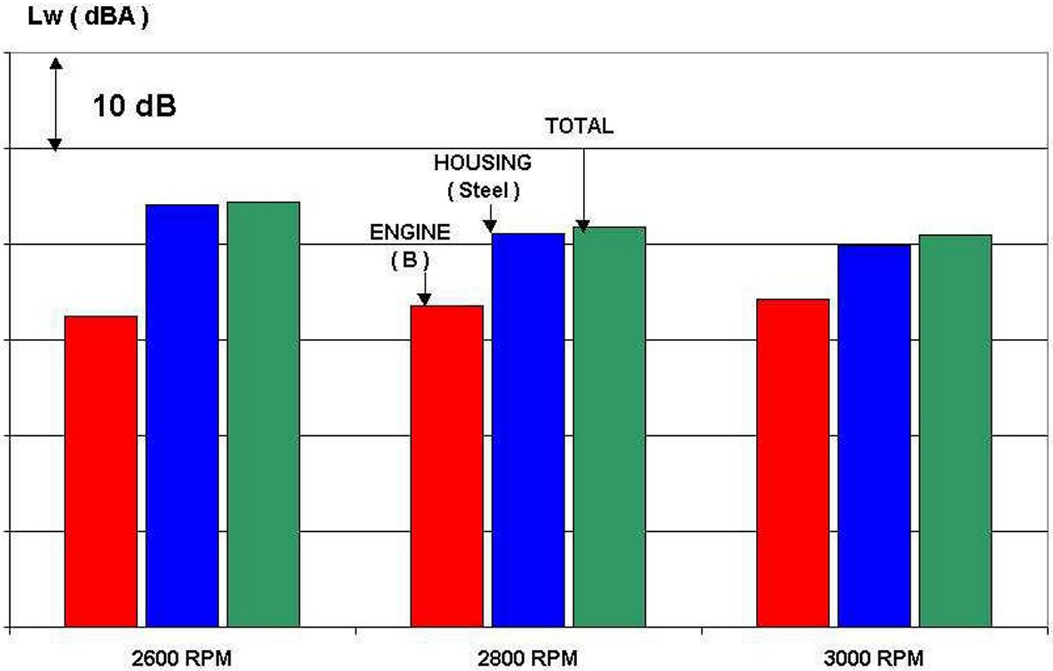


Figure 4: Influence of engine speed.

conditions. It was shown that such information could be obtained from vibration measurements on a "reception plate" to which the component is connected.

In order to improve this method tests have been made with more realistic reception structures. Since structure-borne noise is not characterised in an absolute way by a source strength quantity (as for ex. sound power for airborne noise) but by the response of a particular structure, it may be appropriate to choose a structure comparable with the final support. The results have shown that the use of commercially available lawnmower housings together with a modified definition of structure-borne sound (based on airborne sound quantities) enable to produce much more reliable data. Of course, they still allow ranking of different engines; but what is even more appreciable is the possibility to use these data for prediction purposes in the design process.

REFERENCES

1. *Draft document N98 of ISO/TC 43/SC 1/WG 22. Characterisation of structure-borne sound emission with respect to the airborne sound radiated of connected structures (Reception plate method).*

2. **M. Bockhoff and al.**, Small combustion engines: Structure-borne versus airborne noise, In *InterNoise 97*, pp. 223-226, 1997

3. *NF EN ISO 9614-2, Acoustics - Determination of sound power levels of noise sources using sound intensity - part 2: Measurement by scanning*

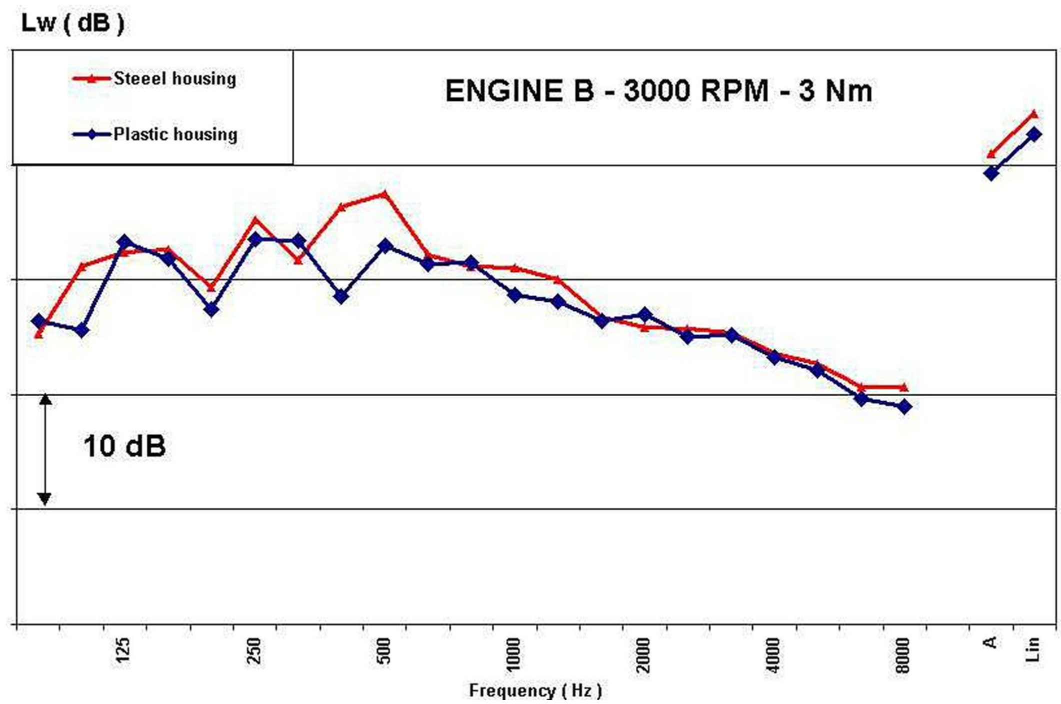


Figure 5: Sound power of reception structure, different housings.