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

I-INCE Classification: 0.0

CHARACTERIZATION OF SMALL CIRCULATION PUMPS AS SOURCES OF VIBROACOUSTIC ENERGY

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Keywords:
CHARACTERIZATION, VIBRATION, ACOUSTICS, PUMPS

ABSTRACT
The characterization method presented here is based on the energetic approach - the pump is characterized in terms of the structure- and the fluid-borne power that it injects in the connected pipe. The powers are determined on a specially designed pipe system from vibration and pressure pulsation measured by an arranged set of 4 accelerometers and 2 pressure transducers. The use of intensity measurement techniques allows to separate both the pipe's vibration and pressure pulsation into the out− and the in−coming waves. The injected power is calculated from experimentally determined amplitude of the out-coming wave, geometric and material properties of the pipe and the internal water. Measurement of the injected power shows to be lowly dependent on the variation of pipe's boundary conditions, which can be considered as a principal novelty concerning this work.

1 - INTRODUCTION

Recently, a need for the method of vibroacoustic characterization of small circulation pumps (P < 200 Watts) arose as they may behave as noise sources in hydraulic systems such as systems of central heating for habitat in which this type of pumps is typically installed.
Under normal operating conditions, a circulation pump behaves as a rather silent equipment - its acoustic radiation is so low that it can be neglected. In fact, the circulation pump behaves more as a source of fluid- and structure-borne noise because it generates vibration and pressure pulsation which may provoke a significant air-borne noise radiation by some other element of the connected pipe system. Therefore, the vibration and the pressure pulsation generated by a circulation pump are of primary concern for its vibroacoustic characterization.
There is a multitude of practical reasons that prevent to conceive a reproducible characterization method based on the measurement of vibration and pressure pulsation directly on the pump. It is thus necessary to make measurements on some other structure. An ideal one would be such on which both vibration and pressure pulsation measurements are possible, which is directly connected to the pump and which impedance can be easily determined. These criteria are all satisfied by the metallic pipe.
Vibration and pressure pulsation in the pipe connected to a pump depend on 2 elements. The first is the pump i.e. its capacity to excite vibration and pressure pulsation - the objective of characterization. The second is the pipe i.e. its ability to admit vibration and pressure pulsation which is characterized through its mechanical and acoustical impedance.
One can imagine several procedures for characterization of circulation pumps on the basis of measurements on the pipe. For example, the levels of pressure pulsation and vibration measured at one or several points of the precisely defined pipe system having either reverberant or anechoic propagation characteristics (the acoustic equivalents are methods based on use of reverberant or semi-anechoic rooms). The main problem with this type of characterization is the difficulty of obtaining reproducible reverberant or anechoic characteristics in low frequencies − circulation pumps are predominantly low frequency sources of vibration and pressure pulsation.
We have therefore decided to characterize the pump through a 2-step procedure based on measurement of the structure− and the fluid−borne intensities in the pipe. The first step is to determine these from vibration and pressure pulsation measured on a particularly designed pipe system having anechoic

characteristics. The second step is to calculate corresponding powers taking into account experimentally determined reflectivity coefficients of the pipe system, which gives a solution for the reproducibility problem in low frequencies. The final result is termed injected or emitted power, which is established both for vibration (structure-borne power) and pressure pulsation (fluid-borne power).

2 - CHARACTERIZATION METHOD

The particular pipe system used for measurements is shown in the figure below.

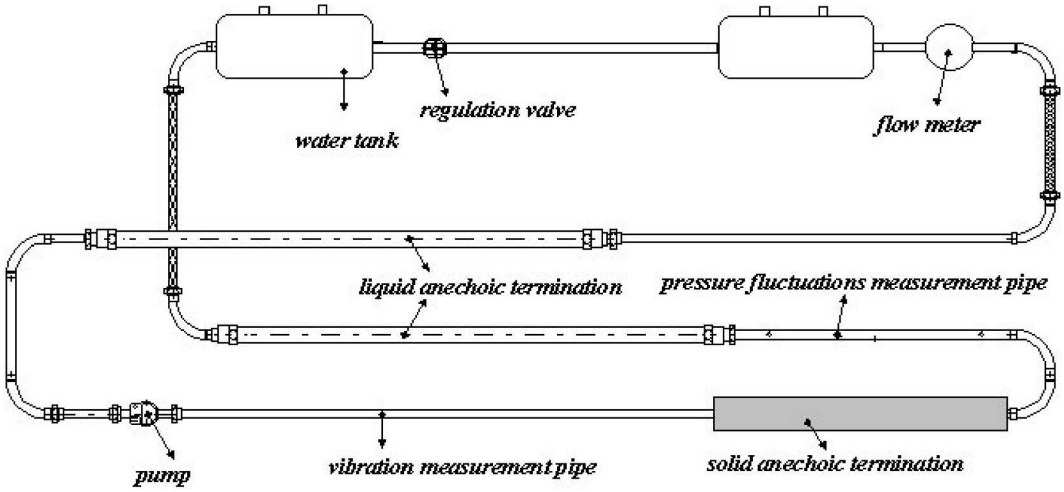

Figure 1: Pipe system used for measurements and its principal parts.

Measurement pipes are made of copper. The role of solid and liquid anechoic terminations is to absorb respectively vibration and pressure pulsation. Two flush mounted pressure transducers are used for pressure pulsation measurements. An array of 4 accelerometers is used for vibration measurements (only bending component is measured). The experimental determination of structure-borne intensity and reflectivity coefficient as well as their fluid-borne equivalents is based on works reported in [1] and [2] and can not be presented in detail for reason of reduced space. We will thus only indicate that structure-borne (sb) and fluid-borne (fb) intensities I as well as structure- and fluid-borne reflectivity coefficients R are distinctive functions of measured auto- and cross-power spectra (G_{xx}, G_{xy}), the distance between sensors δ, geometric D and material properties (E, ρ, c) of the measurement pipe and contained water. This can be symbolically written as:

$$I_\alpha = f\left(G_{XY,}\ \delta,\ E,\ P,\ C\right) \qquad R_\alpha = g\left(G_{XX,}\ G_{XY,}\ C,\ \delta\right) \qquad \alpha = \left\{ \begin{array}{c} fb \\ sb \end{array} \right\} \tag{1}$$

The injected power P is calculated by taking into account the surface of propagation S (which is the median pipe perimeter for vibration and its internal cross-section for pressure pulsation) and the coefficient of reflectivity:

$$P_\alpha = \frac{I_\alpha S_\alpha}{1 - R_\alpha} \qquad \alpha = \left\{ \begin{array}{c} fb \\ sb \end{array} \right\} \tag{2}$$

If one describes the pressure (or vibration) field in the pipe as a superposition of the out-coming and the in-coming wave with respect to the pump, then the injected power corresponds to the power transmitted by the out-coming wave.

3 - MEASUREMENT RESULTS AND CONCLUSION

The robustness of the injected power measurement with respect to a variation of the pipe propagation characteristics is illustrated on 2 examples. The first is given in the figure below and is relative to the case of structure-borne power measurement.

Measured reflectivity coefficients (top diagram) show clearly that boundary conditions on the vibration measurement pipe are largely different - quite naturally, the reflectivity of the pipe without a solid anechoic termination (red curve) is largely superior to the reflectivity of the same pipe having it (blue curve). In consequence, structure-borne intensities are also different particularly in frequencies lower than 80 Hz at which the major part of energy is created. On the contrary, the injected structure-borne

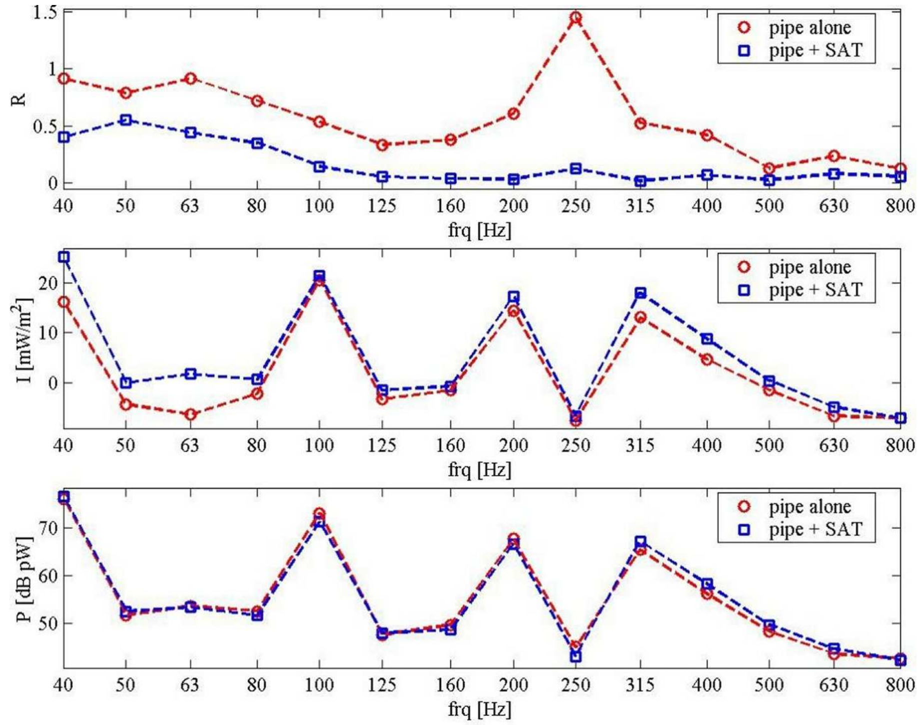

Figure 2: Structure-borne power characterization of the same pump for 2 different boundary conditions; top: reflectivity coefficients; middle: intensities; bottom: injected powers.

powers are rather similar in the whole of frequency band of interest (1/3-octave bands between 40 Hz and 800 Hz).

Equivalent results i.e. the difference between intensities and the similarity of injected powers for different reflectivity coefficients were obtained in case of fluid-borne power measurement (see figure below).

The obtained results indicate that the injected structure- and fluid-borne powers seem to be lowly sensible to a variation of boundary conditions of measurement pipes. One may thus expect that the developed measurement method would produce reasonably reproducible results on a uniform pipe system (such as the one shown in Figure 1). In consequence, this concept of the vibroacoustic characterization of circulation pumps may be applied for inter-laboratory use.

ACKNOWLEDGEMENTS

Authors express their gratitude to members of SCIPION project who financed this work.

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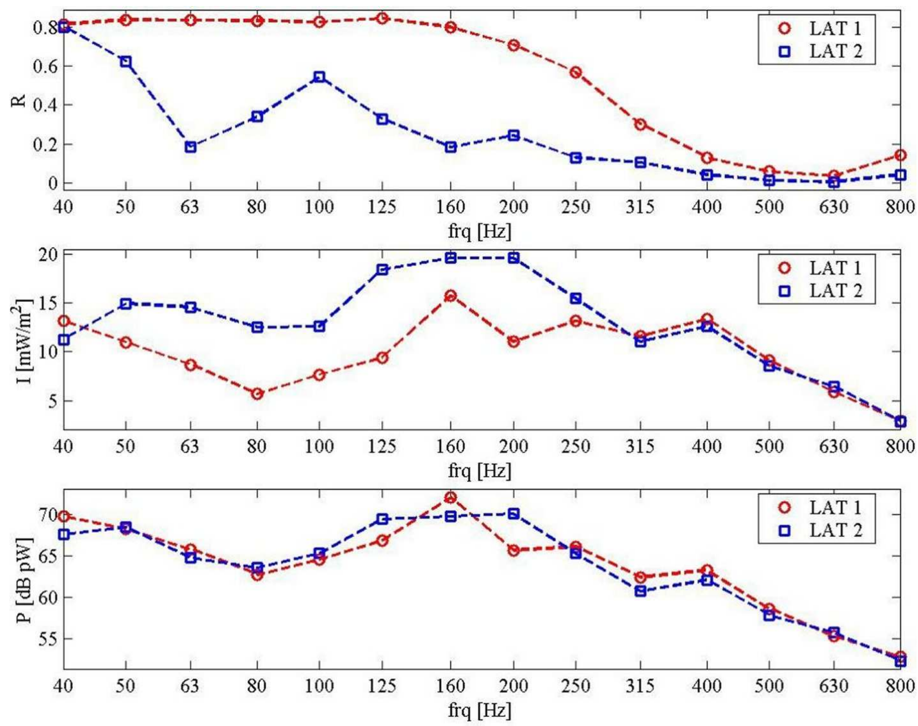

Figure 3: Fluid-borne power characterization of the same pump for 2 different boundary conditions; top: reflectivity coefficients; middle: intensities; bottom: injected powers.