Abstract

Fluid-dynamic noise in hydraulic systems has gained high attention in the last decades due to the increasing requirements of vibration and noise reduction in many fields. Usually the most significant sound sources in the system are fluid machines such as centrifugal pumps, in which flow pulsations are generated with amplitude that depends on the operating conditions (velocity and flow-rate). The resulting pressure fluctuations induced at a given frequency and position along the pipes also depend on the acoustic response of the system, i.e., on how the acoustic pulsations are transmitted or reflected at each system component, including the pump itself. Therefore, the direct measurement of pressure pulsations in a pipeline of a test pump does not directly reflect the acoustic properties of the pump itself, because the coupling effects of the hydraulic system, which can even cause standing waves, may be seriously misleading.

Most of the sound energy in piping systems lays in a range of frequencies low enough for sound to be transmitted only in plane wave mode. In consequence, centrifugal pumps can be considered as two-port acoustic elements with sound generation and sound reflection-transmission properties. The latter are characterized by means of the scattering matrix or the transmission matrix, which establish linear relationships between the acoustic variables (like pressure waves or velocity fluctuations) at the upstream inlet and downstream outlet ports of the pump. This thesis has aimed to investigate the characteristics of the scattering and the transmission matrices of conventional centrifugal pumps with vaneless volute casing, by means of an experimental study on a laboratory pump combined with the development of a special acoustic model.

First, experiments were conducted on a test pump when subject to different acoustic loads that could be induced from an auxiliary pump of the same hydraulic system. In particular, the pressure signals at several positions along the suction and discharge pipes of the test pump were acquired and recorded for a variety of acoustic load configurations. Then, signals were post-processed in the frequency domain to determine the pressure waves travelling up and downstream. And finally, the relationships between the pressure waves at a given frequency imposed by the scattering matrix formed an overdetermined equation system, from which the elements of the scattering matrix could be obtained based on a least square error procedure.

On the other hand, an acoustic lumped-parameter model has been developed to simulate the internal sound field in centrifugal pumps when subject to ideal low-frequency sound sources. The model is based on a network of nodes distributed through the pump, with local transfer matrices connecting pairs of nodes at neighboring regions. This model has been implemented in a numerical procedure to determine the pump passive acoustic properties, either in terms of a transmission matrix or a scattering matrix, as a function of frequency and depending on the main geometrical parameters of the pump. After analyzing the sensitivity of the results with respect to several calculation parameters, predictions have been contrasted against the experimental data obtained for the test pump as well as against the data published in the open technical literature for other nine different pumps. All together, the ten pumps cover a range of non-dimensional specific speeds from 0.25 to 1.01. That contrast was extended to the predictions of the classical Stirnemann's pump model based on an electrical system analogy.

The results show that the predictions of the new transfer matrix model are always in reasonable quantitative agreement with measure-

ments, and that, as frequency is increased, its prediction capability clearly outperforms that of the electrical analogy model regardless the pump specific speed or geometrical features.