Controlling the acoustic resonance in a corrugated flow pipe

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Our study is focused on a phenomenon often encountered in flow carrying pipes, since flow instabilities caused by geometric features may generate acoustic signals and thereafter interact with these signals in such a way that powerful pure tones are produced. Classic examples of flow generated tones are the Aeolian tones heard when a cylinder is put in an airflow, and the tone heard when blowing across the opening of a bottle. In industrial applications such tones may be powerful and, in addition to being annoying, damage machinery due to induced vibrations.

A modern example is found in the so-called “singing risers”, or the gas pipes connecting gas production platforms to the transport network (see fig. 1). These pipes can be very long, i.e. hundred of meters, and are constructed in such a way that on the inside there is a periodic arrangement of cavities (corrugated pipes). The main reason for such a construction is to make the pipes flexible. Dry gas flowing across the cavities may generate high sound levels at some gas velocities. The high sound levels are both annoying and might cause vibration with subsequent mechanical failure. No general mitigation technique has yet been found for this phenomenon, other than reducing the velocity and thereby the gas transport rate. Therefore, the industrial problems caused by singing risers is the inspiration for the present research.

Our general objective is to study the sound producing mechanisms involved when gas is flowing in pipes having one or a system of small cavities. We believe that fully understanding the flow acoustic system will enable us to develop design rules for quiet systems. Such a goal is quite ambitious, and the approach must be both theoretical/numerical and experimental. The practicality of new noise control ideas should also be tested. Some preliminary research involving our three groups indicate that the flow generated resonance in a fully corrugated circular pipe may be silenced by the addition of relatively low frequency flow oscillations induced by an acoustic generator (Kristiansen et al., 2011). When an oscillating flow with velocity magnitudes of the same order as the air flow is added to the main flow, depending on the oscillation strength, the sound emitted by the pipe can be significantly reduced or the resonances moved to higher harmonics (see fig. 2). It was also shown that a low frequency oscillation by itself might excite a higher frequency acoustic resonance of the pipe.

New experiments, aimed at investigating in more detail the coupling between the flow in the pipe, the acoustically generated flow oscillations and the emitted resulting noise are planned and should start within a few weeks. For these experiments, a rectangular partly transparent pipe using glass walls will enable us to use optical techniques to describe in detail the flow field in the corrugation vicinity, with and without the acoustically generated low frequency oscillations. These velocity measurements will, in particular, enable us to determine the modifications which are induced on the flow organization (in terms of coherent structures, turbulence levels, regions of most intense shear, …). The objective is clearly to both understand the origin of the noise generation, and how the acoustically generated oscillations interfere with this in order to either significantly reduce the noise level or modify its peak frequency. In addition, theoretical/numerical work will also be performed, in order to both provide an analytical framework describing the acoustical properties of pipe flows and allow larger-range variations of some of the geometry parameters than available experimentally.

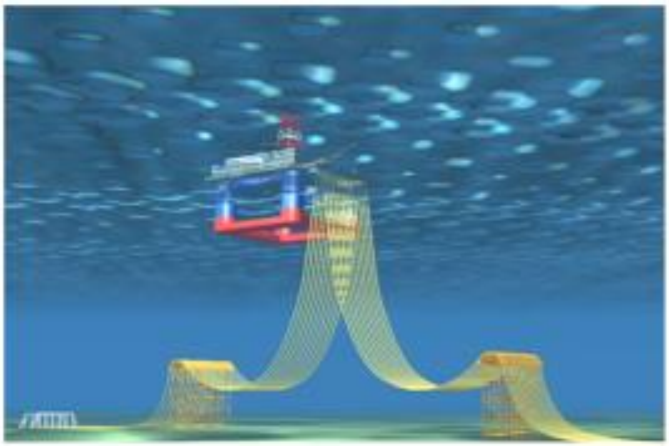

Figure 1. Typical industrial application of corrugated pipes, the riser pipes used in the natural gas industry. Artist impression by Statoil, Norway.

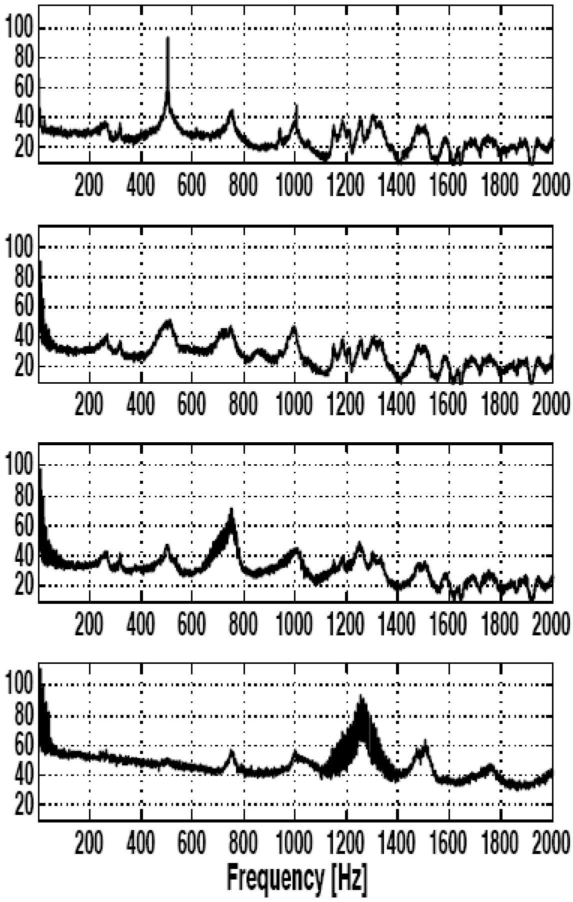

Figure 2. Influence of 10Hz tone on the second longitudinal pipe resonance. Upper figure: resonance generated with flow velocity U = 6.5m/s (no 10Hz tone). Lower panels show the effect of an added 10Hz tone at increasing levels: (0, 90, 97.4, and 110.2 dB). From Kristiansen et al. (2011).

U. R. Kristiansen, P.-O. Mattei, C. Pinhede, M Amielh, 2011, Experimental study of the influence of low frequency flow modulation on the whistling behavior of a corrugated pipe, J. Acoust. Soc. Am., **130**, 1851.

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