STUDY OF NOISE GENERATED BY FLOW VALVES: EVALUATION OF THE EFFECT OF ATTENUATION (ORIFICE) PLATES IN NOISE REDUCTION AND FLUID FLOW EFFICIENCY

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Abstract. *The phenomena associated with audible noise generated by the fluid flow in valves is considered. Control valves as fluid energy control device may often generate undesirable and excessive noise levels, as a result of operational characteristics. A test rig consisting of an arrangement of ducts and reduction valves has been purposely assembled to carry out experiments which are typical of those found in industrial installations. Internal geometry modifications has been accomplished by changing both tubing arrangement and by introducing a varied set of attenuation plates. These attenuation plates introduce fluid flow modifications which can be used in the noise reduction process. Air flow available by means of a compressed air supply originating from a constant volume high pressure reservoir. The contribution of each individual component has been investigated. The main objective is to associate acoustic with fluid flow performance, by means of a series of experiments where a variety of parameters is investigated. The obtained results are used as a design tool in the design of noise attenuation internal plates, which should hopefully help to reduce noise without reducing the efficiency of the system.*

Keywords: *Noise generation by fluid flow, control valves, attenuation plates, pressure losses, fluid-acoustic analysis*

1. INTRODUCTION

Control valves are essential components in any fluid line installation. They introduce however losses and very often undesirable audible noise effects. The latter tend to be more pronounced in industrial installations as a result of a wider variation in flow regime, extreme conditions of pressure and velocity together with a wide range of working fluids. In many typical applications these side effects can pose a most serious problem to the system designer, as they represent both a health hazard and increase in costs (Beranek and Vér, 1992).

Fluid flow generated noise is essentially a function of pressure, velocity and the resulting fluid flow. Since control valves need to introduce an inherent flow restriction in order to operate properly they can be conveniently analyzed as power absorbing devices which convert fluid energy into (for example) acoustic radiation and heat. Furthermore as both phenomena vary according to velocity and pressure variations, and also as the associated generation frequencies are parameter of primary importance to establish proper control measures, and they are influenced by flow profiles parameters, geometry is a major issue. The geometry of valves however, is also determined by constructive restrictions and the available means of control. Also, the effects propagate to other parts of the system and therefore there is an obvious need for a global system design approach. This also means that it may be convenient to observe additional measures taken at other parts of the system It has been found (Wendoloski, 1998) that a most convenient means which help to obtain more desirable characteristics is to introduce perforated disks inside the line, in a position strategically positioned with respect to the control valve. Figure 1 presents an example of this configuration.

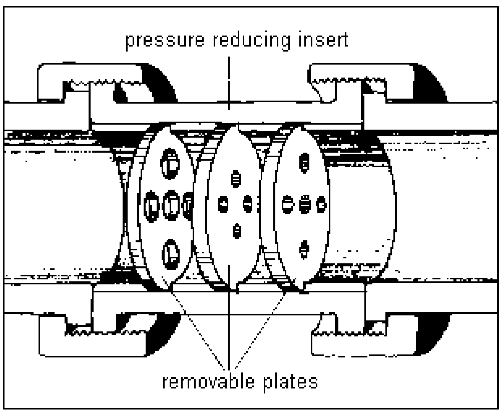

Figure 1 . Typical flow control using perforated disks

2. FUNDAMENTALS OF NOISE GENERATED BY FLUID FLOW

Noise appears as a result of fluid flow for a variety of reasons. A convenient way to describe these phenomena is to organise them according to the following description. Fluid flow noise may result from sonic/shock conditions, velocity variation between two adjacent shear layers, and turbulence (Hover, 1990) It should be emphasised that for applications (Medeiros et. al. , 2007) other than the object of the present study other types of phenomena may also take place.

Open jet noise is usually associated with two components (Dosanjh, 1970) , namely: noise originating from the turbulent mixing layer and noise associated with shock, provided off course that supersonic flow exists). (Collonius et. al. , 1997). The latter effect is usually stronger downstreamwise and the former upstreamwise (Davis et. al. ,1993). The small scale vortices present in the beginning of the mixing zone typically generate high frequency components while larger size vortices, which occur further downstream, produce lower frequency tones. In closed ducts and circuits, the effects are enhanced due to the presence of devices and duct geometry (Michalke 1989).

Since all the previous considerations are essentially a function of the initial pressure and velocity, the relative geometry of a given flow duct and flow interference situations, these are the key considerations for proper control valve associated noise attenuation devices design.

The other consideration, which is extremely important, is how the introduction of these control devices introduce losses in the fluid flow, which is after which defines de operational characteristics of the installation.

3. METHODOLOGY AND EXPERIMENTAL PROCEDURE

3.1. General overview

In order to study the behavior and effectiveness of the noise reducing a series of experiments were carried out at the Fluids Laboratory at the Mechanical Engineering Department of the Federal University of Minas Gerais (DEMEC-UFMG). The installation set up and the sequence of experiments were designed and planned according to information directly obtained from full-scale industrial installations.

The experiments here described correspond to a scaled down version of a real industrial installation.

3.2. Experimental Set-up

The test rig consisted essentially of a system of ducts; a high pressure controlled flow outlet, and a set of noise reducing disks positioned close to the outlet of the installation. The associated measurement sensors and instruments enabled the measurement of pressures, temperatures, and flow velocities. A set of microphones normally positioned at the outlet (reference position for the experiment) of the installation monitored the sound pressure levels for each flow condition. Figure 2 shows a sketch of the experimental arrangement.

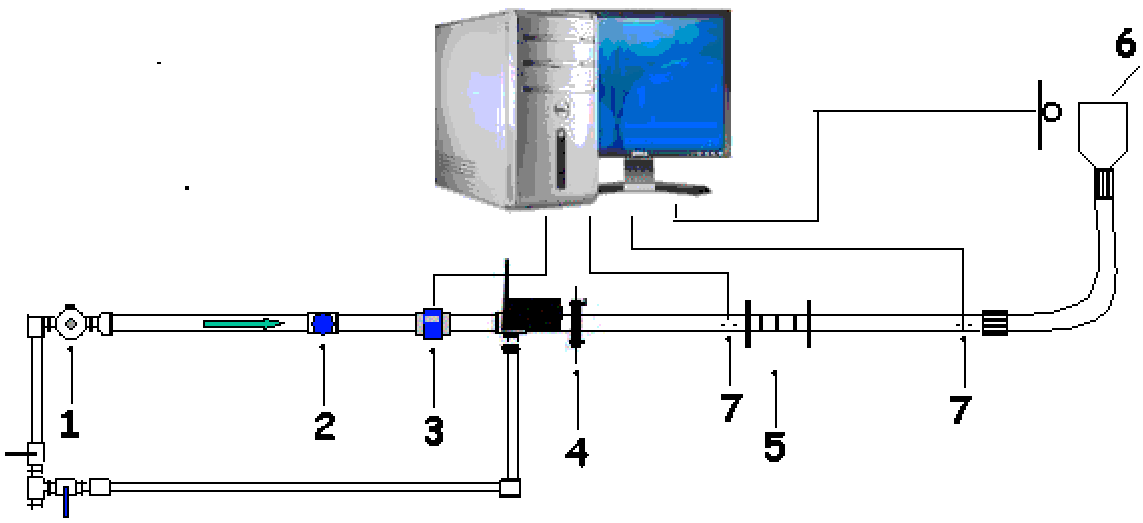

Figure 2. Diagram of the test rig

A number for the sake of convenience indicates the main components. Valve number 01, controls the flow conditions. Points 2 and 3 are pressure and fluid flow points. The control valve object of the present study is positioned at position 4 and the disks at position 5. The outlet 6, where a microphones are positioned, may also be changed to provide the desired flow conditions. Compressed air is applied at the entry point where the two flow control valves meet.

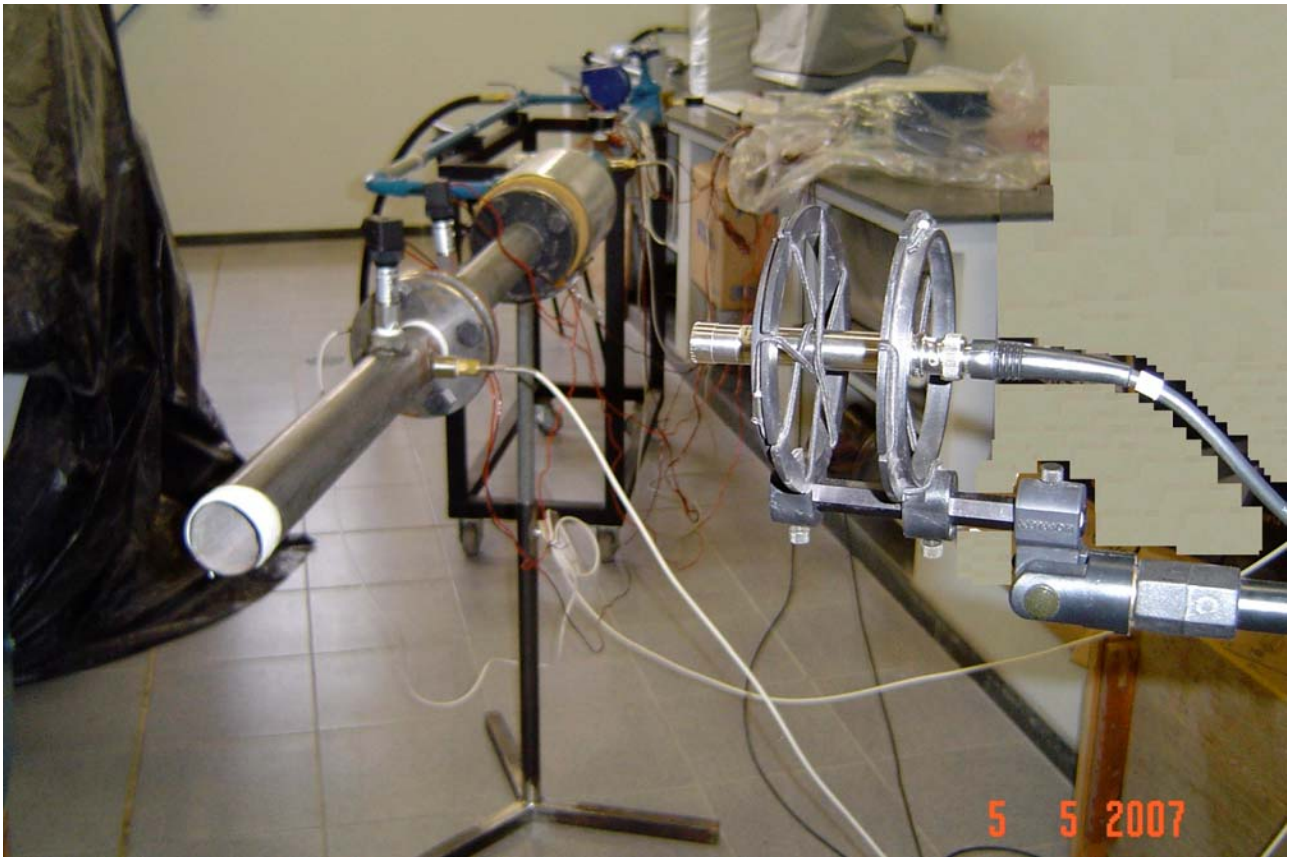

Figure 3. Photograph of the test rig

Figure 3 shows some of the details of the test rig. At the forefront, a pair of measurement microphones can be observed.

The experiments have been carried out for a variety of flow regimes, and test valve setting. The set of perforated disks changed several times in order to test the effectiveness of each configuration. Sonic condition has been achieved but the measurements have stopped when the Mach number reached unit due to the presence o choking.

All the noise measured flow parameters have been checked with a comparison of results involving a multipoint measurement where pressure, temperature and velocity were observed.

The observed noise levels refer to the output measured at the outlet, as shown in the photograph. Background noise has been measured at the start of the experiment and found to be at least 50 dB (NPS) lower than the values obtained with the rig in operation. This is a very important consideration, as the test room is not acoustically insulated. It should be emphasized however that reverberant conditions were not found to be a major parameter of concern.

A typical set of results is presented in the text, which follows.

4. RESULTS

Figures 4 and 5 represent typical results obtained during the experiments. Figure 4 shows how effective perforated disks are as a noise reducing device, for a series of flow regimes, with a range starting at low subsonic velocities going up to Mach = 1.

In the very low frequency range a considerable scatter is present. This effect is associated with a very complex behaviour where structural coupling takes place and both air borne and structure borne transmission paths are important. Even though the disks modify the local stiffness, and hence the structure-borne transmission, they are essentially flow conditioning devices, and more effective as flow induced noise control devices. The very low frequency range measurement has also been contaminated by environmental background noise. and by the increase of electrical sensor noise in the low frequency range. As a consequence the results below 63 Hz have not been reliable, even though a small qualitative noise attenuation can be observed, even for the low frequency range. For the range above that the results have been fairly consistent.

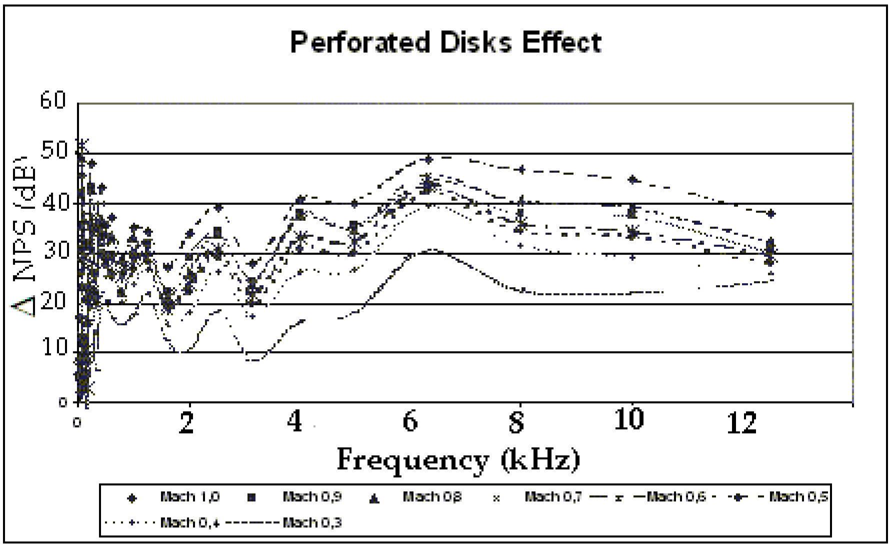

Figure 4. Perforated Disks Attenuation

It is interesting to observe that the noise attenuation devices here presented are unsurprisingly more effective at noise reduction in high Mach number (high speed) range. As a flow regularization device they tend to lower the local Mach number, and hence reducing compressibility effects. Also, as noise generation is a function of total flow energy, at lower speeds noise diminishes naturally and flow regulation effects become less noticeable.

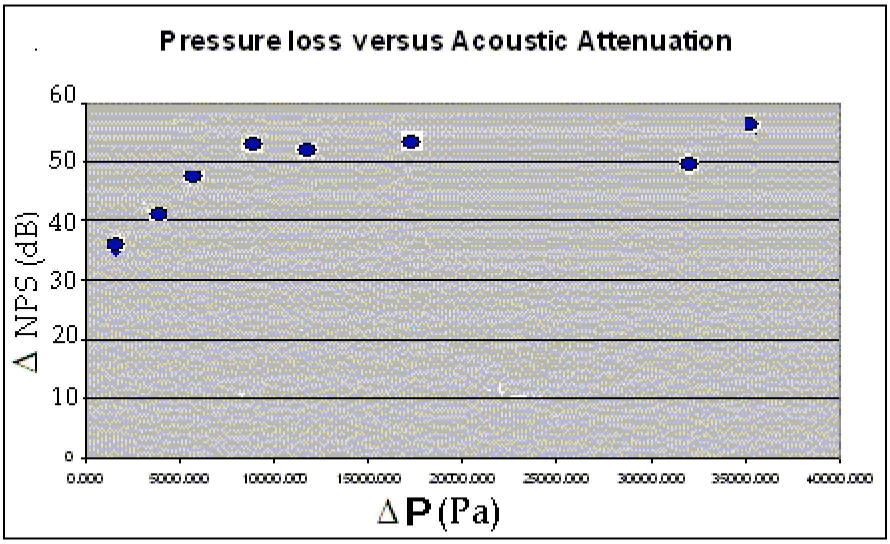

Figure 5. Pressure loss and noise attenuation

Any noise-reducing device should not introduce energy losses into the main process. Figure 5 represents an average for a series of measurements and provides an indication of the penalty in terms of pressure loss, which is associated with noise attenuation. As lower attenuation is associated with lower speeds it is not surprising that lower attenuation is related to smaller pressure losses. At the other end of the range very high losses may occur at high speeds. In fact the effect of pressure losses at high speeds in fluid carrying ducts with the introduction of flow carrying devices was only to be expected. Also designers should avoid compressible flow effects in order to minimize both noise and pressure losses in ducts. On the other hand, the noise reducing devices here presented have to dissipate fluid flow energy in order to regularize the fluid flow and hence minimize noise effects. As a consequence it appears that the here described noise reducing devices are recommended in conditions where either high Mach numbers are not to be reached or when high pressure losses can be tolerated. In fact Figure 5 indicates that very high pressure losses are to be observed for these high energy flow conditions, an effect which is not accompanied by a corresponding increase in the noise attenuation efficiency, and hence are not to be recommended.

5. CONCLUSIONS

A system consisting of perforated disks have been developed in order to provide attenuation of audible noise generated by control valves. The system has been tested in a range of conditions starting in the low subsonic range, going up to the sonic condition and proved to be very efficient for a variety of fluid flow conditions. Pressure losses have also been measured when these devices are introduced. It has been found that even though these devices provide consistent noise attenuation for most of the operational range, higher attenuation is achieved for higher speeds. However pressure losses are to be seen as a serious restrictions in the higher Mach and speed range. As a consequence for the sake of overall efficiency, these higher speeds are to be avoided.

6. ACKNOWLEDGEMENTS

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5. RESPONSIBILITY NOTICE

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