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A STUDY OF DUCT VENT SILENCER

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Abstract

The behaviour of a typical blow-off (high pressure discharge) noise attenuator has been investigated. In the present study a series of experiments have been carried out for a typical silencer. Compressed air with controlled pressure and flow was supplied to a line equipped with a so-called down termination attenuator. The internal geometry of the diffuser and of the so-called acoustic core has been varied and a series of experiments have been carried out for several flow and pressure conditions. The noise attenuation for each condition has been evaluated for a set of standard SPL octave bands and associated with the corresponding fluid losses obtained at the output. The objective has been to associate acoustic efficiency with reduced pressure losses, which are not only detrimental in terms of efficiency but also increase line supply costs. Finally, the potential use of the present study is discussed as a tool, which in the design process of typical venting silencers.

INTRODUCTION

Discharge lines are commonly found in industrial compressed air and vapour installations. They represent an intrinsic feature in these applications, as they provide a convenient control and safety device. Direct venting to the outside environment would produce unacceptable noise levels without the use of venting silencers which help to reduce this effect to more acceptable levels.

Fluid flow generated noise is essentially a function of pressure, velocity and the resulting fluid flow. Typical silencers [2] use this principle to initially raise the noise spectrum to higher values of frequency modifying the velocity and pressure fields, providing components which are easier to attenuate in another noise absorbing stage. A typical silencer incorporates not only resistive elements but also acoustic reactances which contribute to the overall noise attenuation process.

Since the gas to be vented to the outside is normally thrown away, it would appear that fluid flow losses could be unimportant or even sometimes desirable as they could provide an additional means of acoustic energy dissipation. However excessive pressure losses inside the silencer make gas discharges difficult, and may even introduce unwanted fluctuations and safety hazards in the main gas line. Proper attenuation design involves therefore a detailed analysis of acoustic parameters such as noise spectrum and sound pressure levels together with fluid flow regime and pressure loss evaluation.

ESSENTIALS 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. It should be emphasised that for applications [3] 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[1], namely: noise originating from the turbulent mixing layer and noise associated with shock, provided off course that supersonic flow exists. The latter effect is usually stronger downstreamwise and the former upstreamwise [4]. 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.

Since all the previous considerations are essentially a function of the initial pressure and velocity, the relative geometry of a given flow channel and flow interference situations, are most important considerations for proper silencer design.

EXPERIMENTAL PROCEDURE AND SETUP

Since full-scale operation of an attenuator is expensive it has been decided to make use of a scaled down installation. Furthermore a full industrial installation could not be easily tested under controlled laboratory conditions. In this initial study it has been decided not to use a silencer containing a very large number of reactive stages which is in any case to be avoided for economic (manufacturing) reasons both in the industrial and reduced scale cases Flow regime similarity has been established by using the Mach number as a reference.

Experimental Set-up

The experiments have been carried out at CETEC-MG (The Technological Centre of Minas Gerais State) since this research institute has a Gas Flow Laboratory capable of supplying high pressure compressed air with precisely controlled conditions. The test rig consisted essentially of a system of ducts; a high pressure controlled flow outlet, and a scaled down typical industrial silencer and the associated measurement sensors and instruments. Figure 1 shows a sketch of the experimental arrangement.

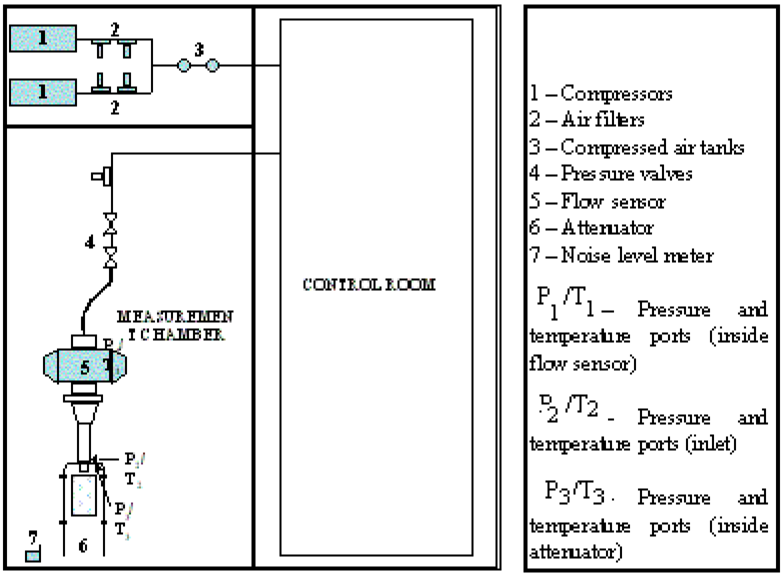

Figure 1 – Experimental arrangement

Two high pressure compressors provided the necessary compressed air via a set of pressure (control) reservoirs. A system of valves enabled the control of the required pressure and flow. The noise attenuator was positioned at the end of the line, in a “venting” condition, exactly as it happens in an industrial installation. The test room has been designed to provide low noise and controlled temperature and humidity conditions. In order to reduce the influence of sound radiation from the line walls in the measurements, classical insulation and flexible coupling elements were also employed. Figure 2 provides an additional visualisation of the test rig.

Figure 2 – Test line and silencer

The basic noise attenuator configuration is sketched in Figure 3. It was constructed in separate parts to enable configuration change, such as changing the diffuser and the absorbing core. The main body and the diffuser were fabricated with low grade Carbon steel sheets, the inner core absorbing material being mineral wool. The basic attenuator sizing criterion has been the ability of the supply line to provide well controlled high pressure compressed air. The dimensions varied for different test sessions. Typical values used in the experiment were (Figure 3): a = 0,25m, B=0,075m, C=0,2m, 1,5<L<2,5m, DNx=0,019m.

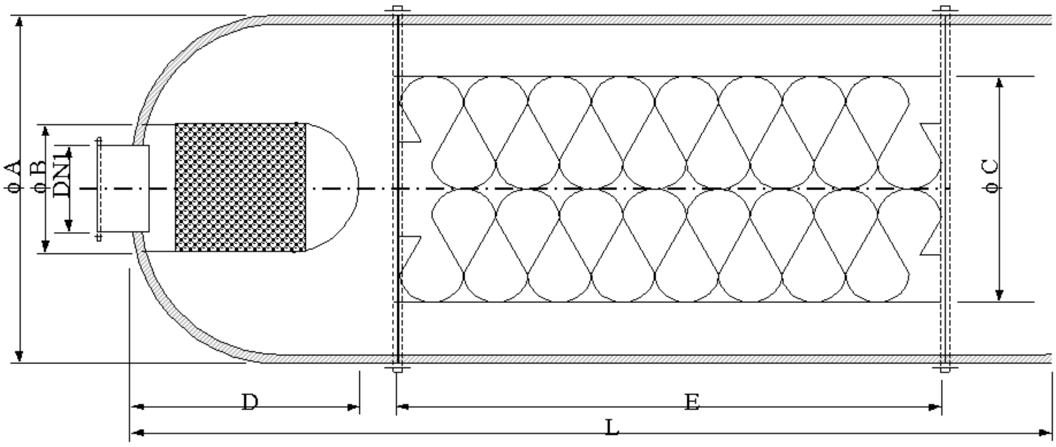

Figure 3 – Silencer basic configuration

Experimental Procedure

The test procedure started with the evaluation of environmental conditions such as: temperatures, background noise and humidity. Following that several different assemblies were mounted. The items which were changed were the diffuser (Dx), the silencer core(Nxxx), and silencer length (Lx), where x indicates an index which is an identificator number. Figure 4 shows the three diffusers which have been used so far in this experiment.

Figure 4 – Diffuser configuration

Temperatures, pressures, and fluid velocities were measured and evaluated along the line and compared with overall sound pressure levels obtained at the outlet port (venting) of the installation. together with the associated noise levels, for each test condition

RESULTS

The experiments produced a set of results, for each configuration, which can be conveniently organised in two classes, namely: a) obtained noise attenuation as a function of flow regime, and b) pressure loss as function of flow regime. The two sets of results were compared in order to associate pressure loss along the line with the obtained noise attenuation.

In order to obtain an idea of the influence of each component in the overall system performance change of configuration also involved removing and/or adding components to the system, even if sometimes the system would not operate in normal service without a particular component. Figure 3, for example, shows how core changing or removal may affect the overall performance.

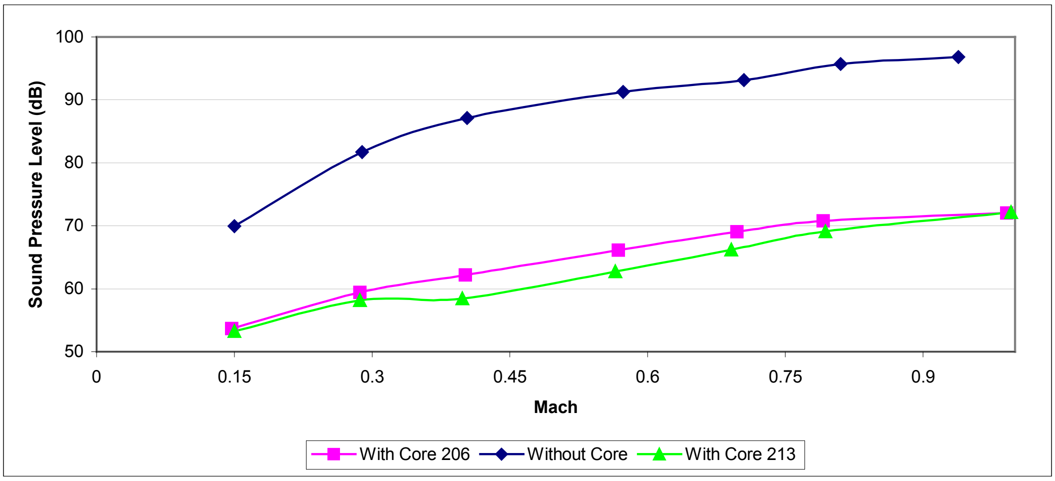

Figure 3 – Effect of the silencer core

The overall performance has also been associated with the contribution of local pressure losses for each component. Figures 4 and 5 are an important example of this procedure, indicating how the acoustic performance may vary by changing the diffuser and associating these results with the associated pressure losses for each part of the diffuser. A typical procedure may be exemplified as follows. The total pressure loss in the diffuser (h_{LT14}) may be conveniently distributed into three components, namely:

- h_{L12}: distributed loss (mainly friction) associated with the inlet tube length
- h_{Lm23}: local pressure drop due to the inlet expansion
- h_{Lm34}: local pressure drop, associated with the perforations of the plate

$$h_{LT14} = h_{L12} + h_{Lm23} + h_{Lm34} \qquad (1)$$

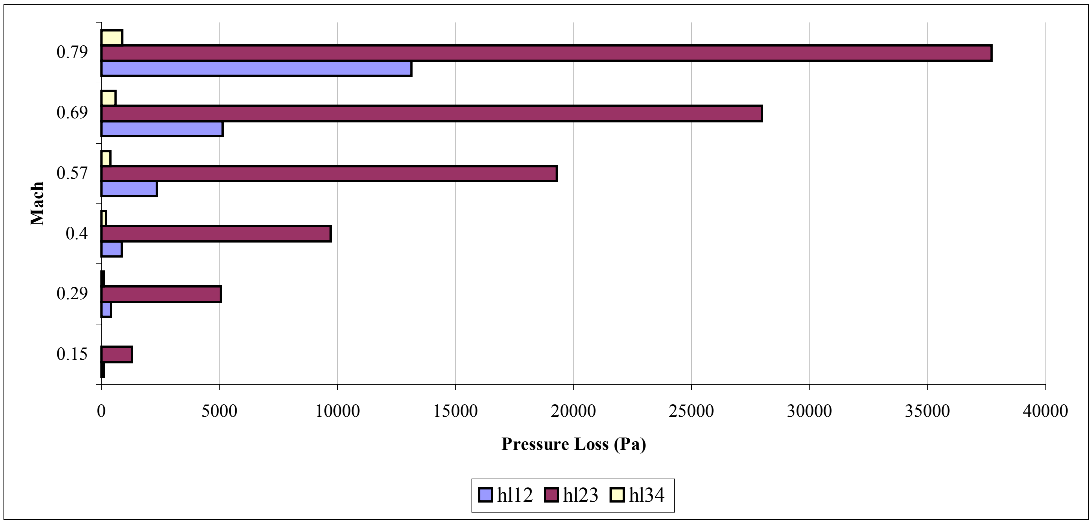

Figure 4 – Pressure loss for each component of the diffuser (influence)

It is possible to observe by looking at Figure 4 that the pressure loss (hL34) due to the gas expansion at the diffuser has the most significant influence on the pressure loss. This is incidentally a valuable guideline in an overall design optimisation process. These results could then be compared with the acoustic performance, typified by Figure 5, for each flow regime.

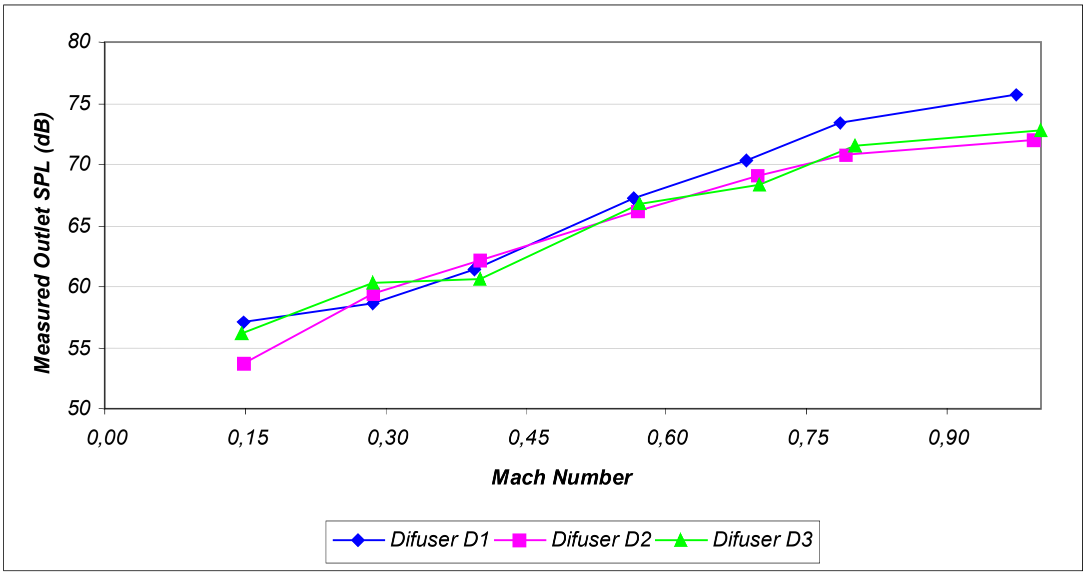

Figure 5 – Effect of changing the diffuser

Each set of measurements has also produced a noise spectrum output such as the one exemplified by Figure 6, which provides an additional insight of silencer performance when the diffusers are swapped.

Noise spectrum is a most useful feature for this problem as it provides not only an insight into diffuser performance but also because it is helpful in determining fluid flow behaviour, since noise generation phenomena is also a function of flow mechanisms.

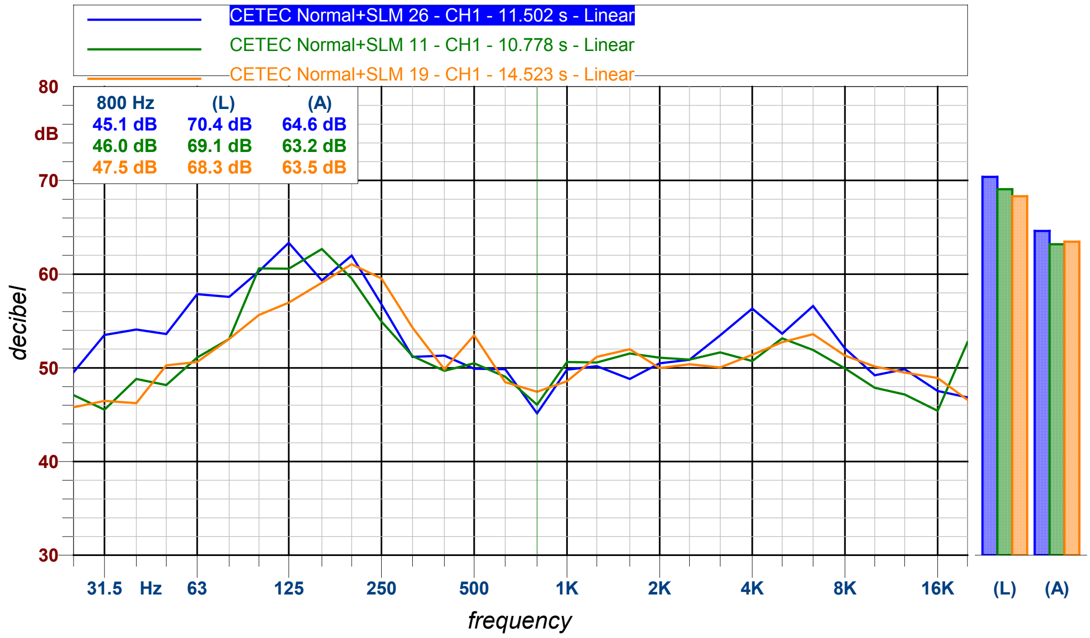

Figure 6 – Spectrum for different diffusers at Mach=0.7 SLM26→D1, SLM11→D2 SLM19→D3

It should be emphasized however, that additional (and intensive) testing is needed which should also comprise flow visualization in order to be able to identify more fully the local flow phenomena associated with noise generation.

Table 1 indicates how typical configurations performed both in terms of noise attenuation efficiency and pressure loss. In this particular comparison, the attenuator length (L1) and the core parameters (L206) have been kept constant and three different diffusers were tested.

Table 1 – Typical silencer global attenuation and pressure loss

TEST SEQUENCE						
Mach Number	Configuration					
	D2 – L206 – L1		D3 – L206 – L1		D1 – L206 – L1	
	SPL (dB)	ΔP (Pa)	SPL (dB)	ΔP (Pa)	SPL (dB)	ΔP (Pa)
0.15	53.67	67	56.19	62	57.12	155
0.3	59.44	341	60.38	266	58.57	573
0.4	62.18	683	60.66	530	61.33	1118
0.6	66.16	1447	66.76	1060	67.18	2458
0.7	69.06	2664	68.32	2079	70.38	4029
0.8	70.81	8763	71.49	7369	73.33	9722

CONCLUSIONS

The previously discussed study has confirmed the suitability of the proposed method as a useful tool in the determination of blow off silencer behaviour. It has been possible to observe well known features such as frequency conversion and filter behaviour for a given attenuator. As expected, the present study has confirmed that proper evaluation of acoustic performance requires an analysis of the associated fluid flow regime. It should be mentioned that the latter also introduces a cost factor, which should always be kept in mind by the designer. Geometric considerations, therefore, such as tube length, perforation diameters and contraction ratio have to be carefully considered in order to achieve a more satisfactory overall efficiency. It means that the dimensions should be matched not only according to the acoustic wave length under consideration but also by helping to provide more suitable discharge and flow scavenging conditions. Unsurprisingly some of the components, in particular the diffuser, have proved to be more sensitive for this kind of analysis. As such, this component has deserved a separate analysis which has indicated that gas expansion at the nozzle is the main factor in the determination of pressure losses.

Regarding spectral analysis as a tool to identify operational conditions it is probably a useful tool but still requiring further testing in order to obtain more useful criteria, particularly as in many cases different flow regimes may produce a similar spectral pattern.

Finally, it should be mentioned that the present research is still current, and a better definition for some of the parameters is already on the way.

ACKNOWLEDGEMENTS

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