Sensitivity of frequency response to type of tubing

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1. Introduction

Windtech Consultants uses measurements of the frequency response of the tubing system to digitally filter the pressure signal obtained during a wind tunnel test. Irwin *et al* (1979) has demonstrated that distortion effects due to the effect of tubing response can vary the peak pressure by as much as 12 percent. The current general opinion is that the type of material does not have a significant impact on the frequency response of a tubing system, provided that the geometric properties are the same. This paper shows how tubing made from slightly different material can have a significant impact on the frequency response of the pressure measurement system.

2. Methodology

The equipment used to determine the response of the tubing system consists of a National Instrument Data Acquisition Card (PCI-MIO-16E-4) linked to an Endevco Model 8510B-1 piezoresistive microphone as the reference, which has a specified uniform response (within ±0.5dB ie. ±5.9%) from DC to 4,000Hz. The Endevco reference "transducer" was connected to an Endevco 4428A pressure signal conditioner. The Windtech pressure measurement system was represented by a DUXL05D pressure transducer. The National Instruments data acquisition card generated a sinusoidal fluctuating pressure signal, which controlled a 50W TOA TU650 driver. The output signal from the driver is then directed to a T-connector. The reference signal is obtained via the Endevco microphone attached directly to one of the side pins of the T-connector. The test signal is measured off a DUXL05D pressure transducer connected to a 500Hz analogue low-pass filter and using different tubing configurations.

Both the test signal and reference signal are processed by a LabView data acquisition program to produce an amplitude ratio and phase difference between the two signals. The LabView transducer calibration program calculates the FFT of the two signals (in terms of amplitude and phase). The amplitude ratio is the amplitude of the FFT signal of the test signal at the relevant frequency divided by the corresponding value in the reference signal. The phase difference is the difference between the phase of the FFT of the test signal and the reference signal. The experimental setup is described in Figure 1, below. Tests were carried out using different tube lengths, tube diameters and different tubing materials. The Figure 2, below shows the types of tubing used in this study. Table 1, below summarises the different tubing configurations tested.

Table 1: The different tubing configurations tested

I.D. (mm)	Length (mm)	Material
1.1	25	Stainless Steel
1.4	25	Soft PVC
1.5	25	medium hardness PVC
1.5	25	hard PVC
1.5	1000	soft PVC
1.5	1000	hard PVC
1.5	1500	soft PVC
1.5	1500	hard PVC

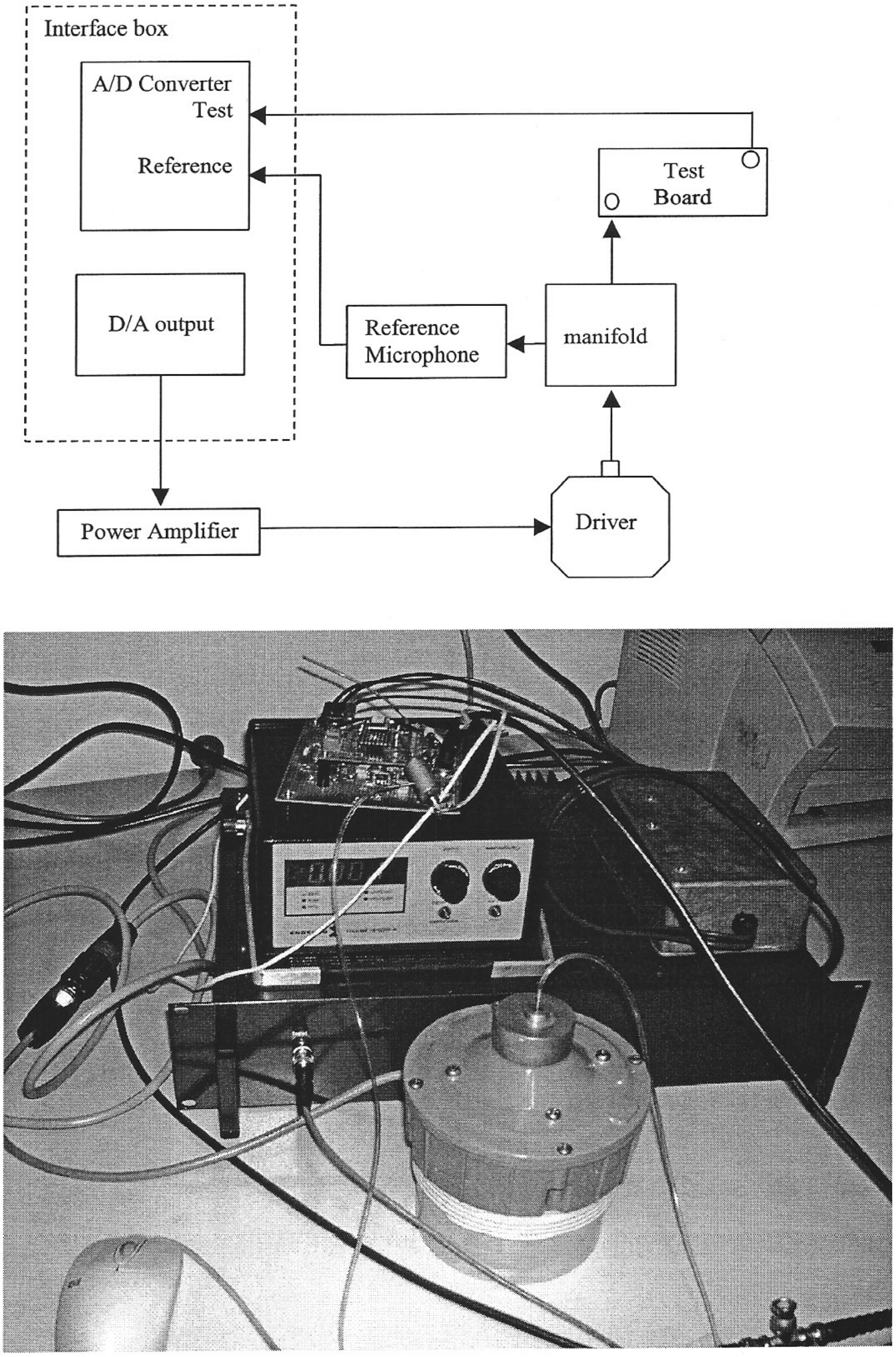

Figure 1. Test setup

Note that for the specified nominal lengths of 1000 and 1500mm, these are the lengths from the pressure tap connector box. For these lengths, the actual lengths are 150mm longer than specified to account for the section of tubing from the connector to the transducer.

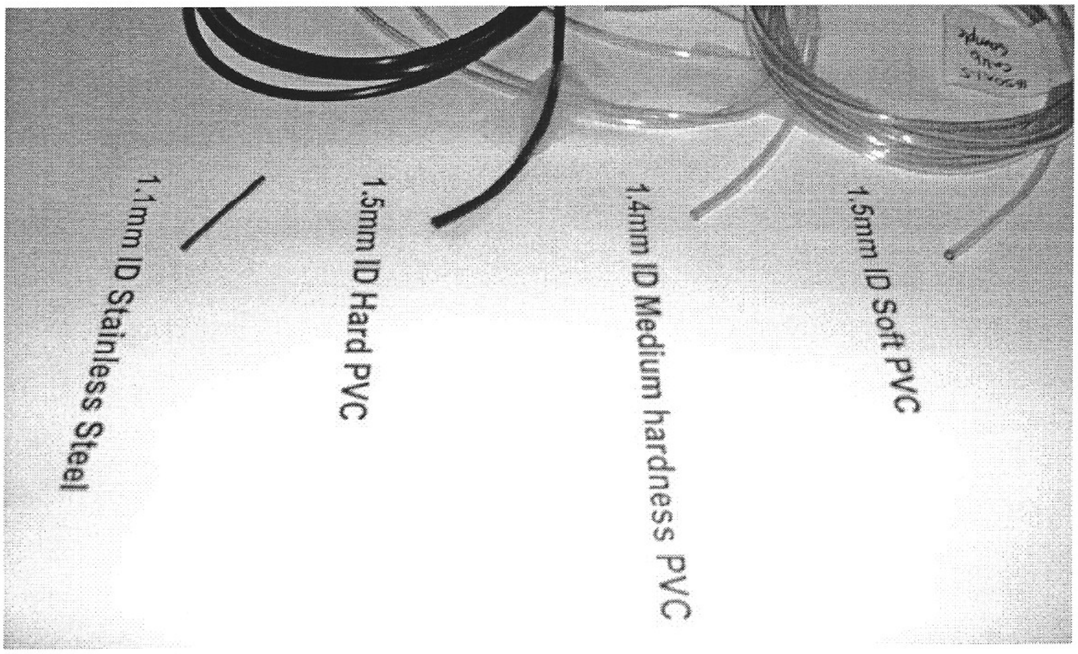

Figure 2. Photograph of the different tubing types used.

3. Results and Discussion

The comparative results for the different materials are presented in Figures 3a, 3b and 3c, below. Figures 3a and 3b present comparative results for 1500mm and 1000mm nominal lengths, respectively. In each figure, the results are presented for the soft PVC and the Hard PVC tubing with all other dimensions being the same. The only difference is that the soft PVC tubing has a slightly larger wall thickness.

In Figure 3c, the effect of 4 different material types is investigated for a 25mm short tube.

The results indicate that the longer the tube the greater the effect of the material properties of the tubing. Figures 3a and 3b indicate that for long tube lengths the soft PVC tube has a much greater damping effect on the frequency response of the tubing.

For the short tubing, the reverse seems to be the case for the three types of PVC tubing. This is possibly due to the ability of softer tubing to resonate with the pressure pulse more than the harder tubing in the very short tube configuration. The fact that the 1.4mm ID tubing falls within the same trend with respect to the material property, despite it being different to the 1.5mm ID for the other PVC tubing suggests that the effect of the material property may be more important than the effect of the tube dimensions. This view is also supported by the results presented in Figures 3a and 3b.

The response of the stainless steel tubing seems to have the highest resonant response may be due to the effect of the material properties as well as the smaller diameter.

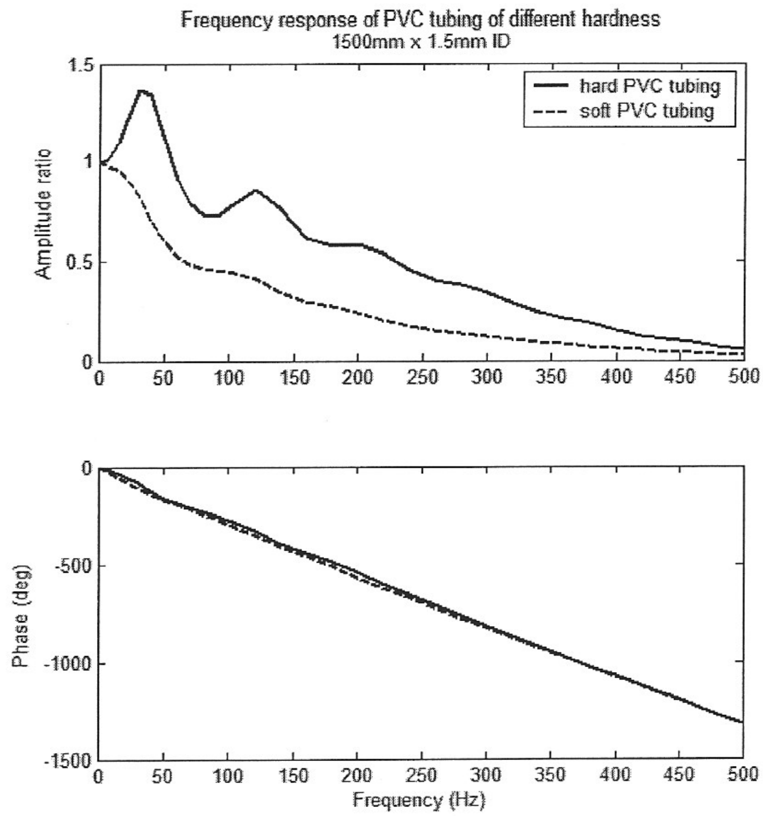

Figure 3a. Comparison of frequency response of different material tubing using 1500mm long tubing.

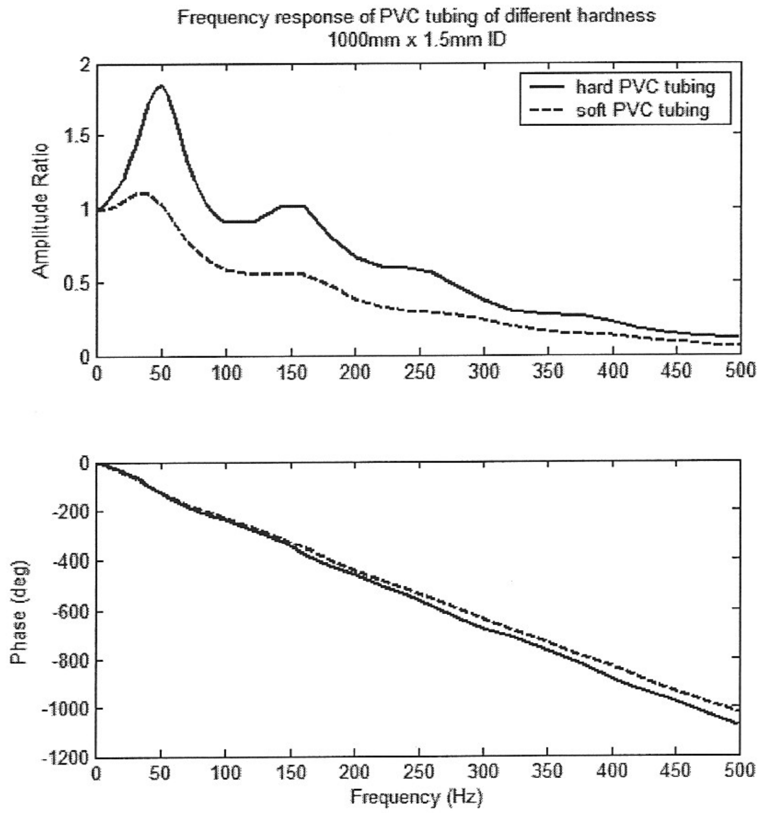

Figure 3b. Comparison of frequency response of different material tubing using 1000mm long tubing.

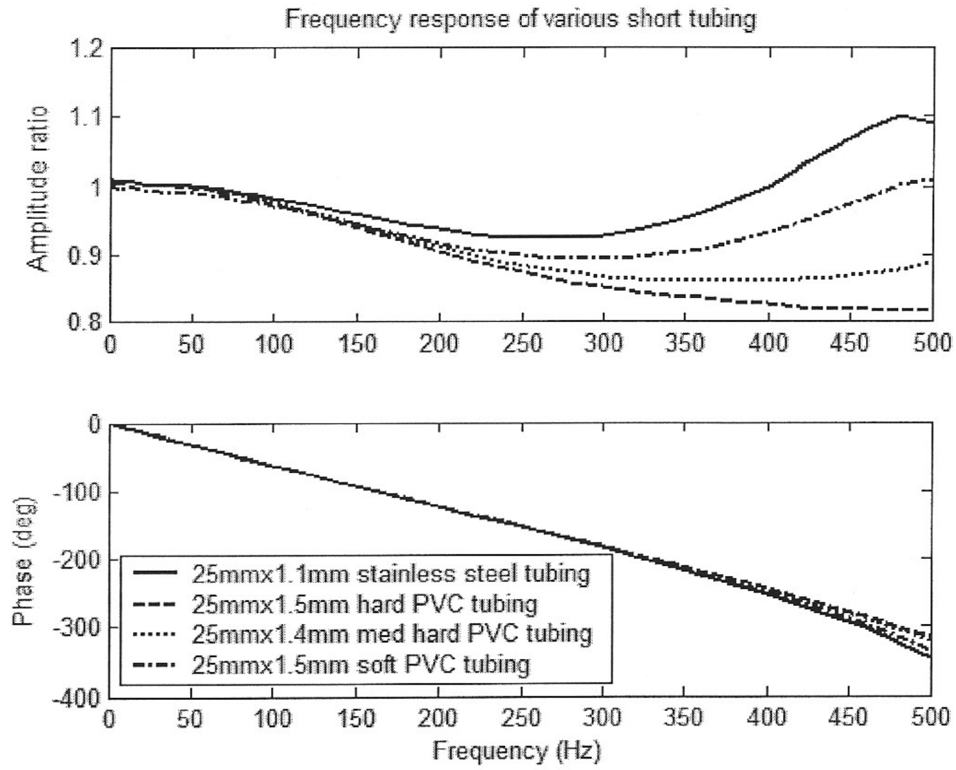

Figure 3c. Comparison of frequency response of different material tubing using short tubing.

References:

H.P.A.H. Irwin, K.R. Cooper and R. Girard, "Correction Of Distortion Effects Caused By Tubing Systems In Measurements Of Fluctuating Pressures" J. Ind. Aero. Vol. 5, pp93-107, 1979.