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Technical note

Measurement of flow noise generation and pressure loss of nets and screens

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ABSTRACT

Nets, screens and grids are often used to either reduce or generate turbulence for aeroacoustic testing in wind tunnel facilities. It is hence important that the self noise generated by such devices due to the flow is considerably lower than the noise sources to be examined.

In order to obtain a basic understanding of the aerodynamic noise generated by nets and screens, a detailed experimental study was performed on a large number of nets of varying parameters. This included the measurement of the pressure loss and the determination of the sound power generated by the nets. The resulting one third octave band sound power levels were then used to derive a simple empirical prediction model for the noise generated by such devices.

1. Introduction

Nets, screens and grids are commonly used in aeroacoustic testing facilities in order to reduce turbulence, for example in turbulence control screens [1–3]. On the contrary, such devices can also serve to purposely generate turbulence with a certain intensity and length scale, for example for the experimental investigation of turbulence interaction noise. Other applications of nets and screens include, for example, wind deflectors for convertible cars. In all cases, however, a minimum generation of aeroacoustic noise is usually desired.

Despite the fact that nets are widely used for such applications, there exist only a limited number of studies on their generation of aerodynamic noise. Besides the noise generation, the pressure loss due to such devices is also of interest, as are the characteristics of the turbulence generated.

The early experimental study by Gordon [4] on the flow noise radiated by different types of spoilers in a pipe provides some basic results that could also be important when examining the noise generated by grids. For example, it was found that the overall sound power radiated by the spoilers is proportional to the sixth power of the flow speed and to the third power of the total pressure drop.

A detailed work on the noise generated by grids in a flow was done by Hubert [5], who performed measurements on eight different grids, consisting of perforated plates, ventilation grilles, wire meshes and arrays of bars. Based on the results he proposed an empirical model for the prediction of the overall sound power level. In agreement with the findings of Gordon, Huberts model contains the dependence of the overall sound power on the sixth power of the flow speed and on the third power of the pressure loss coefficient.

Scheiman and Brooks [2] measured the pressure loss and turbulence characteristics of a set of flow manipulators (screens, honeycomb grids and combinations of both). They found the pressure loss coefficient to be a function of the porosity of the screens and, to a lesser account, of the Reynolds number based on wire diameter. In this work, however, the noise generation of the flow manipulators was not examined.

A detailed investigation on the generation of turbulence by grids of varying geometry was performed by Roach [6]. In addition, the pressure drop across the grids was examined. Similar to the results from [2], the pressure drop was found to be mainly governed by the grid porosity, but also by Reynolds number, Mach number and grid geometry. Again, no acoustic measurements were performed.

This short overview shows that there is only a very limited number of experimental studies of the noise radiated by nets, screens or grids in a flow. Furthermore, existing noise prediction models are mainly concerned with the prediction of the overall sound power level. In order to expand the existing data basis, the present paper contains the results of a detailed experimental study, in which the noise generation and the pressure loss of a large number of different nets and screens were determined inside an aeroacoustic wind tunnel. Thereby, the aim was to examine nets with a large variety of geometrical properties and to use the resulting data to derive a basic model for the prediction of sound power level spectra. The remainder of this paper is organized as follows: Firstly, the materials and methods used are described, including the nets, the wind tunnel facility and the measurement techniques. Secondly, detailed results are presented only briefly, as they are used in the final section to derive a basic empirical noise prediction model.

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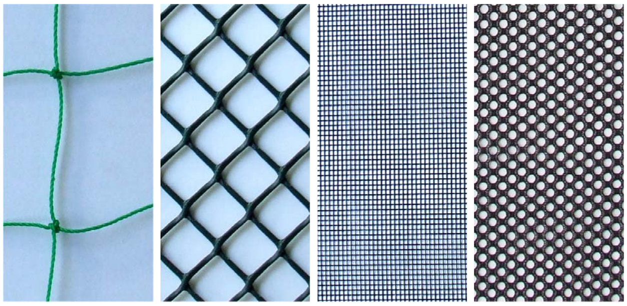

(a) net 5 (b) net 19 (c) net 25 (d) net 33

Fig. 1. Photographs of nets used in this study (all images show a section with a size of 0.05 m × 0.1 m).

2. Materials and methods

2.1. Nets and screens

The aim of the study was to investigate the influence of the parameters that define the geometry of the nets on the noise generation. To this end, a large variety of different nets and screens was acquired. This included materials like mosquito nets, curtain cloth, tulle, badminton nets and thin foam materials. In total, measurements were performed on 58 different nets. However, some of the materials were not found suitable during the experiments, for example when they were strongly deformed due to the dynamic pressure. This left 42 nets for the final analysis. As an example, Fig. 1 shows photographs of four nets used in the experiments.

In order to characterize the geometry of the nets, the materials were scanned, using a common flat bed scanner with a resolution of 1200 pixels × 2400 pixels. Then, three different parameters were obtained from these scans using a raster graphics editor:

1. the porosity σ, defined as the ratio of open spaces (holes or pores) to the total area,
2. the averaged width of the open spaces h and
3. the averaged width of the filaments b.

The parameters h and b are shown schematically in Fig. 2 for an example net. In addition to these three parameters, the thickness t of the materials was measured. An overview of the nets used in the present study is given in Table 1.

2.2. Wind tunnel

All experiments took place in the small aeroacoustic open jet wind tunnel at the Brandenburg University of Technology at Cottbus [7], using a nozzle with a rectangular exit of 0.15 m × 0.2 m. This cross section corresponds to the area S of the nets that is subject to the flow.

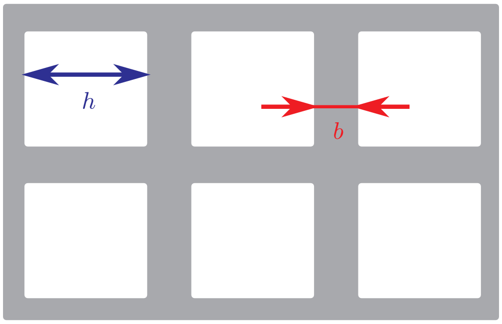

Fig. 2. Schematic of an example net, showing the averaged width h of the open spaces and the averaged width b of the filaments (not to scale).

Table 1
Overview of the nets.

Net no	σ in %	h in mm	b in mm	t in mm	$\bar{\zeta}$
1	0.966	100.05	1.25	1.32	0.023
2	0.956	13.5	0.3	0.22	0.025
3	0.953	104.4	1.3	1.4	0.005
4	0.943	151.7	3.2	1.8	0.153
5	0.937	60.75	1.2	1.2	0.024
6	0.914	34.7	1.25	1.3	0.073
7	0.867	26	2.05	1	0.084
8	0.860	53.95	3.9	3.2	0.226
9	0.841	1.975	0.15	0.26	0.191
10	0.812	2.075	0.15	0.22	0.189
11	0.807	0.45	0.2	0.18	0.640
12	0.790	37.1	4.8	3	0.359
13	0.779	32.55	3.15	2.2	0.305
14	0.767	32.35	4.2	2.8	0.317
15	0.746	1.75	0.225	0.23	0.272
16	0.724	7.15	0.95	1.7	0.789
17	0.721	16.4	2.05	1.3	0.436
18	0.706	1.9	0.375	0.16	0.420
19	0.706	16.8	1.85	1.6	0.310
20	0.693	16.65	2.65	1.5	0.495
21	0.661	5.85	1.1	1.64	0.732
22	0.641	1.325	0.35	0.28	0.971
23	0.637	5.35	0.95	0.46	0.756
24	0.613	0.925	0.25	0.25	0.762
25	0.603	1.25	0.375	0.26	1.279
26	0.601	4.25	1.025	0.57	0.968
27	0.595	6.75	1.6	1.15	0.940
28	0.573	1.6	0.5	0.3	0.894
29	0.552	2.1	0.5	0.57	1.097
30	0.542	4.25	1.3	0.7	1.401
31	0.535	2.1	0.55	0.53	1.214
32	0.517	6.1	1.5	0.5	0.911
33	0.506	2.85	2.45	0.3	1.839
34	0.504	0.25	0.1	0.11	0.840
35	0.481	0.6	0.15	0.19	1.534
36	0.466	2.875	0.75	0.43	1.125
37	0.461	9.4	3.1	1.25	0.838
38	0.456	3.95	1.5	0.75	1.983
39	0.450	1	0.55	0.26	2.264
40	0.422	1.9	1.25	0.22	2.175
41	0.393	1.25	0.925	0.15	2.152
42	0.342	3.65	1.8	0.7	0.659

The nets were attached to the nozzle exit using a special frame with the same dimensions as the nozzle exit. Thus, the nets were tightly fixed between the nozzle and the frame, which featured a notch to prevent any misalignment. The flow speed in the experiments was set by adjusting the pressure in the settling chamber of the wind tunnel and measured using a Pitot tube positioned downstream of the nets.

During acoustic measurements, the test section in front of the nozzle was surrounded by a cabin with absorbing materials attached to its walls (with the exception of the one opposite of the nozzle), resulting in an anechoic environment for frequencies above approximately 125 Hz. Thus, acoustic measurements were analyzed in a range of frequencies from about 200 Hz to 20 kHz.

2.3. Acoustic measurements

The acoustic measurements were performed using eight one fourth inch MI-17 free-field microphones, positioned outside of the flow at a distance of 0.8 m from the nozzle center. Four of the microphones were positioned on the nozzle exit area, with an angle of 90° to the wind tunnel center line and angles of 45°, 135°, −45° and −135° to the vertical axis. The other microphones were positioned with the same angles of 45°, 135°, −45° and −135° to the vertical axis, but with an angle of 45° to the wind tunnel center line. Fig. 3 shows a photograph of the acoustic measurement setup.

The measurements were performed using a National Instruments 24