Silent owl flight: experiments in the aeroacoustic wind tunnel

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Introduction

While it seems to be common knowledge that owls generate less noise during flight than other birds, only a few studies give quantitative proof for this observation. Additionally, some of the published studies are very old, and therefore the acoustic measurement techniques are not comparable to modern measurement techniques that are common today, like microphone arrays and high resolution multichannel data acquisition systems.

Graham [1] was the first to examine the plumage of owls and to determine the mechanisms enabling the quiet flight in 1934. Other basic studies of the sound emission of owls are fly over measurements, like the work of Kroeger [2] and Neuhaus [3]. The paper of Lilley [4] aims to give a very simple estimation for the sound emitted by flying birds.

Aerodynamic experiments on birds or bird wings were done for instance by Pennycuick [5], Tucker [6] and Withers [7]. While the first two did measurements involving living birds flying in an open jet wind tunnel with an adjustable axis, the latter focused on experiments using prepared bird wings only.

As part of an ongoing research program on the silent flight of owls, the Aeroacoustics Group of the Brandenburg University of Technology at Cottbus is currently working on fly over measurements and experiments on prepared bird wings in an aeroacoustic wind tunnel. The present paper is based on the latter. It describes aeroacoustic measurements on different prepared bird wings in an open jet wind tunnel. Preliminary results are given for a chosen subset of the wings.

Measurement Setup

All measurements took place in the aeroacoustic wind tunnel in Cottbus which is an open jet wind tunnel. For the experiments a circular nozzle with a diameter of 0.35 m was used, allowing for flow velocities up to approximately 25 m/s. The turbulence intensity in front of the nozzle is in the order of 0.3 % at 20 m/s. The A–weighted wind tunnel self noise sound pressure level at this velocity is below 44 dB (at a distance of 1 m at 90° to the axis). The test section in front of the nozzle is surrounded by a cabin, of which the side walls are lined with porous material to achieve a semi–anechoic acoustic environment for frequencies above 500 Hz. The wings were attached to a specially built six–component–balance and positioned in front of the nozzle. Special care was taken for the design of the mounting that was used to connect the wings to the balance. It had to be adjustable

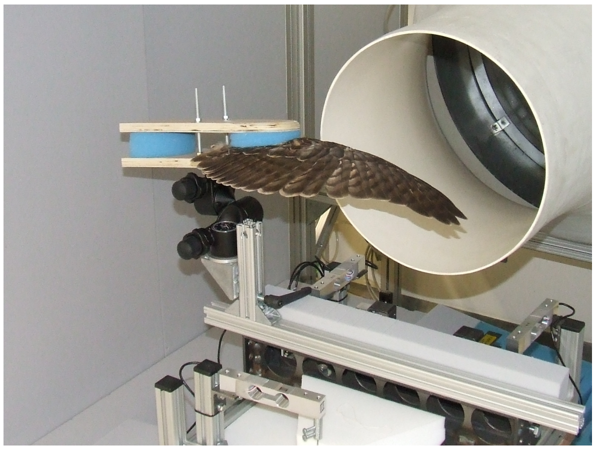

Figure 1: Setup showing the semi–anechoic cabin, the circular nozzle and a prepared bird wing (sparrowhawk, right wing) attached to the six–component–balance with the designed mounting

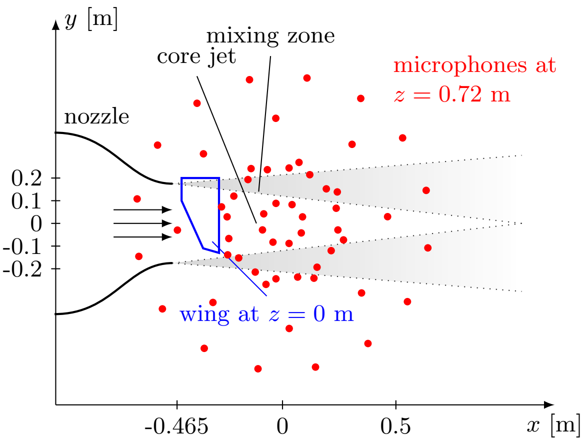

Figure 2: Schematic display of the measurement setup (top view)

within certain limits to different wing geometries in order to be of use for all the wings that were examined during the measurement campaign. Additionally, two requirements had to be met regarding the shape and material of the mounting: First, no aeroacoustic or aerodynamic effects must occur at the mounting and thus distorting the measured data of the bird wings. And second, the specimen had to be attached tightly without causing any damage to the feathers or the bones. The resulting clamp has a simple geometry and is equipped with a soft foam to prevent the wing specimen from damage (see Figure 1).

The acoustic measurements were done using a planar 56–channel microphone array positioned 0.72 m above the wings outside of the flow. Advanced beamforming algorithms, like the orthogonal beamforming [8], were used to process the data. Sound pressure level spectra were obtained from the beamforming maps by integrating over an area containing the complete bird wing subject to the flow.

The lift and drag forces generated by the different wings in the free stream were measured simultaneously using the six–component–balance. However, the aerodynamic results are not reported here.

The geometry of the wings was measured with a 3D digitizer system. Seven wing specimen of four different species, of whom two belong to the order of the (silent flying) owls, were used for the experiments. Of the non silent flying species, two wings belonged to the Common Buzzard and two to the Eurasian Sparrowhawk. The silent flying birds were represented by two wings of the Tawny Owl and one wing of the Barn Owl. The description of the wings and of certain aspects of the measurement setup is made using the nomenclature of technical airfoils. The effective area is the part of the wing area in front of the nozzle (the "projected" area). The averaged chord length c_l was obtained from the effective wing area S and the halfspan h_s, being the distance between the wing tip and the arm bone at the position where it is attached to the mounting:

$$c_l = \frac{\mathrm{S}}{\mathrm{h_s}} \tag{1}$$

For the reason of simplicity, in the following section only two out of the seven prepared bird wings examined in the experiments are used to present the results. These are the wings of the eurasian sparrowhawk (*Accipiter Nisus*) as a representative of the non silent flying birds, and of the tawny owl (*Strix Aluco*) as a representative of the silent flying owls. The sparrowhawk's wing has an effective wing area of 0.0365 m^2, a halfspan of 0.355 m and an averaged chord length of 0.103 m, the tawny owl's wing has an effective area of 0.0382 m^2, a halfspan of 0.320 m and an averaged chord length of 0.120 m. Both wings were chosen because they have similar effective wing areas and both are left wings (see Figure 3). It has to be noted that only one aspect of the complex bird flight, the gliding flight, is examined. During this flight phase, the wings remain at an approximately constant angle of attack and no flapping occurs.

(a) Sparrowhawk

(b) Tawny owl

Figure 3: Prepared bird wings used for the presentation of the results

Results

Measurements were conducted at three different angles of attack (0°, 8° and 16°) and 14 flow speeds ranging from 7 m/s to 20 m/s. In accordance to [7], the angle of attack was measured at mid–span, and changes to the angle caused by the flow (natural twist and aerodynamically induced bending) were not corrected.

Figure 4(a) shows the measured power spectral density (PSD) of the two wings, the level is higher for the sparrowhawk's wing over the whole range of frequencies. Figure 4(b) gives the third octave spectra of the sparrowhawk wing and the owl wing. The sound pressure level (SPL) generated at the wing of the sparrowhawk is noticeably higher at all frequencies than that generated at the owl's wing, with level differences from 3 to 5 dB.

The overall sound pressure level ($OSPL$) for the third octave band, with center frequencies chosen to be between 800 Hz and 16 kHz, is defined as:

$$OSPL = 10 \cdot log_{10} \left(\sum_{f_m = 800 \text{ Hz}}^{16 \text{ kHz}} 10^{[SPL_i/(10 \text{ dB})]} \right) \text{dB}, \tag{2}$$

where SPL_i is the sound pressure level at the third octave band i. The dependence of the measured $OSPL$ on the flow velocity U is given in Figure 5. As expected, the noise generated at the hawk's wing exceeds the noise generated at the owl's wing at all flow velocities.

Figure 6 shows some sample sound maps, each calculated using a common delay-and-sum beamforming algorithm. For each given third octave band, the sound pressure level emitted by the sparrowhawk's wing is higher than that emitted by the owl's wing. Additionally, the area of the wing containing strong sound sources is greater for the hawk than for the owl. Most of the noise is generated at the surface of the wings near the trailing edge. The wing tips do not seem to be very strong noise source locations for both wings at this flow velocity.

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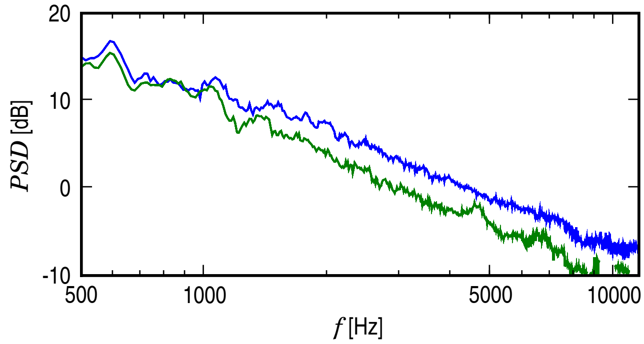
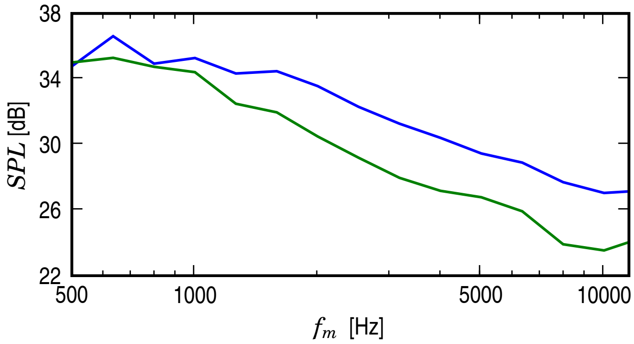


(a) Level of the sound pressure $PSD\ re\ 4 \cdot 10^{-10}\ \mathrm{Pa}^2/\mathrm{Hz}$



(b) Third octave spectra of the sound pressure level

Figure 4: $U = 11.5$ m/s, $\alpha = 0°$ (— Sparrowhawk, — Tawny Owl).

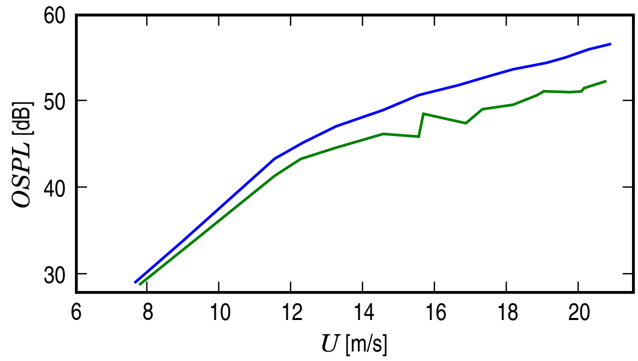


Figure 5: $OSPL$ as a function of the flow velocity U at $\alpha = 0°$ (— Sparrowhawk, — Tawny Owl).

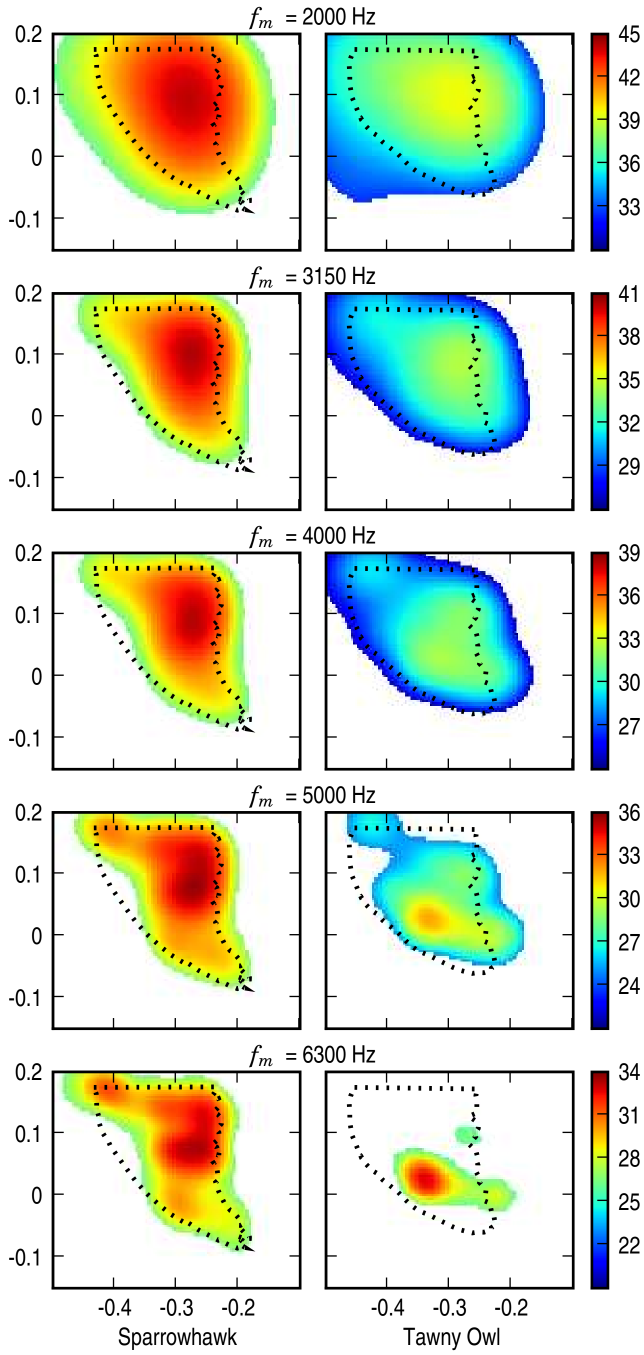


Figure 6: Sound maps at $U = 20$ m/s and $\alpha = 0°$, third octave band (view from above, flow from left to right).

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