The Aeroacoustics of the Owl

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Abstract The secret of certain owl species enabling them to fly stealthily is investigated and adapted to the suppression of aeroacoustic noise at the trailing edge of a wing or blade. Two features from the owl are mimicked: the poro-elastic trailing edge in the owl's feather, and the fibrous canopy structure above the nominal wing surface. Initial modelling and experimental results demonstrate up to 10 dB noise reduction over a wide frequency range without reducing aerodynamic performance.

Keywords Aeroacoustics • Biomimicry

1 Introduction

Many species of owl can hunt in acoustic stealth. The question of precisely how the owl actually manages to fly so quietly has remained open. However, it has long been appreciated that owls which need to hunt silently possess two unique features, which are not found on any other bird, and indeed are not even found on owls which do not need to hunt silently (e.g. on small owls which feed on insects, or Fish owls). First, the microstructure of the feathers on the upper wing surface is exceedingly complex, with an array of hairs and barbs which form a thick canopy just above the nominal wing surface—see Fig. 1. Second, the wing trailing edge possesses a small flexible and porous fringe—see Fig. 2.

Our research objective is to answer the following two questions: First, how do these two features of the owl actually work to suppress noise? And second, can we learn something form the owl which can be applied in engineering practice? The first question is exceedingly complex, and as I will describe has only been partially

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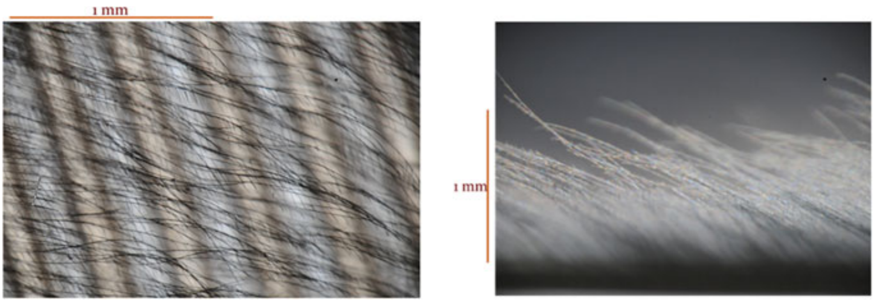

Fig. 1 Top and side view of upper surface of wing feather, Great Grey Owl

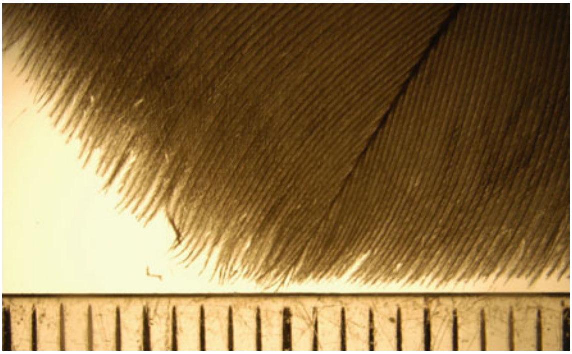

Fig. 2 Trailing edge fringe, Siberian Eagle Owl. Scale in 1 mm gradations

answered to date. However, we have made definite progress with the second question, and I will present very promising test results for an owl-inspired trailing-edge noise reduction device. The research I am going to describe is part of an ongoing theoretical and experimental program between Cambridge, Virginia Tech, Lehigh University and Florida Atlantic University.

2 Modelling and Results

A theoretical model for the trailing-edge fringe has been developed in Jaworski and Peake (2013), where we consider the sound scattering properties of a poro-elastic trailing edge, which crucially is seen to be significantly less noisy than a rigid trailing edge. In Clark et al. (2014) we conduct both experimental and theoretical studies of the feather micro-structure, and demonstrate that the canopy observed in Fig. 1 can have a very significant effect in shielding the surface from the unsteady pressure fluctuations associated with the turbulent boundary layer (inclusion of a canopy composed of a relatively open fine fabric mesh can lead to reductions of up to 30 dB in the surface pressure spectrum). This observation has led us in Clark et al. (2015) to present a trailing-edge noise reduction device which makes use of this canopy effect. Sample results are given in Fig. 3, where we show sound intensity maps for a tripped DU96 (wind turbine) blade at $Re = 3 \times 10^6$. Without the treatment most of the noise comes, as expected, from the turbulent boundary layer passing over the trailing edge. However, significant noise reduction (in this case up to 10 dB) is seen once the device is included, over a wide range of

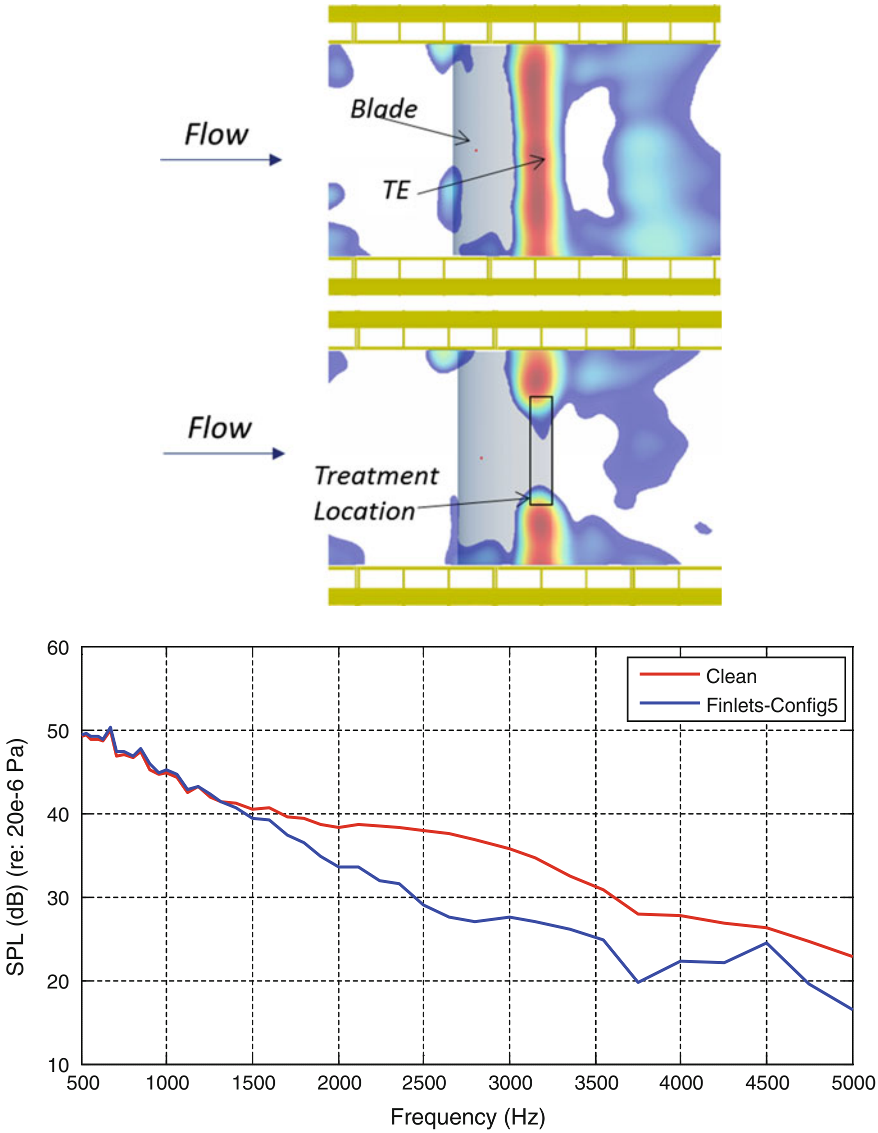

Fig. 3 Sample results; noise map at single frequency, and power-integrated spectrum

frequencies. The device will be described in detail in the presentation, and full details are given in Clark et al. (2015). Interestingly, preliminary results indicate that the device has only a very small effect on the aerodynamic performance of the aerofoil, and that noise suppression is retained over quite a wide range of angles of attack and tunnel speeds.

3 Further Work

A range of further wind-tunnel testing to produce an optimised design is currently being completed. Theoretical investigations into better understanding the canopy mechanism are also continuing; some explanation can be found from shear sheltering, whereby unsteady disturbances in the upper boundary layer are shielded by mixing layer just above the canopy, but further calculations are required. Effects of spanwise flows and angle of attack are also being considered theoretically.

References

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