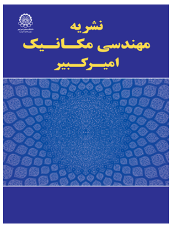

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Experimental Investigation of the Performance of Trailing Edge Noise-Reducing Finlets

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ABSTRACT: In the present study, the efficiency of the finlet as a means of passive trailing-edge noise control has been experimentally investigated. Surface pressure spectra, spanwise length scale, and eddy convection velocity in the trailing-edge region are important parameters in determining far-field trailing-edge noise. In the present study to measure the above parameters, a flat-plate model equipped with unsteady surface pressure transducers has been designed and built. Results have shown that the flow behavior downstream of the finlets is strongly affected by the spacing between the finlets. The use of finlets with coarse spacing leads to a reduction in the surface pressure spectrum at mid to high frequencies and an increase in the spanwise length scale at low to mid frequencies. On the other hand, for the finlets with fine spacing, while the surface pressure spectrum has been further reduced at high frequencies, there has been an undesirable increase at low to mid frequencies. Moreover, fine finlets can significantly reduce the coherence and eddy convection velocity at mid to high frequencies. Finally, the Amiet-Roger model has been used to evaluate the changes in far-field trailing-edge noise and the results have shown the effectiveness of finlets in the mid and especially high frequency range.

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1- Introduction

In recent decades, increment in noise pollution due to the increasing development of the transportation industry, wind turbines, cooling and heating systems, etc. has caused many undesirable effects. During past decades, noise and acoustic pollution have received less attention than other man-made pollution. Noise pollution can be caused by several mechanisms, including aerodynamic noise. Airfoil noise is one of the aerodynamic noises which is caused by the interaction of unsteady flow with an airfoil's surface. In 1989, Brooks divided the mechanisms of airfoil noise into five groups [1]: 1- turbulence boundary layer trail-edge noise, 2- laminar boundary layer vortex shedding noise, 3- separation (stall) noise, 4- trailing-edge bluntness vortex shedding noise, and 5- wing tip vortex noise. Among aforementioned noises, turbulent boundary layer trailing-edge noise is one of the most important sources of aerodynamic noise in aircraft, submarines, wind turbines, and fans, and therefore in recent decades, many studies in the manner of analytical, numerical, and experimental research have been performed on it [2, 3].

To reduce trailing-edge noise, various passive airfoil noise-control methods have been developed, such as trailing-edge serrations, trailing-edge brushes, porous trailing edge, airfoil shape optimization, trailing-edge morphing, and recently upstream finlets, which is inspired by the anatomy of silently flying owls [4, 5].In the present study, the effects of finlets with different spacing on the mean surface pressure distribution, the surface pressure spectra, the frequency-dependent spanwise length scale, the eddy convection velocity in the

trailing-edge region and far-field trailing edge noise of a flat plate are investigated.

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2- Experimental Setup

The flat-plate model, the arrangement of the microphones on the model, and the geometric characteristics of finlets are illustrated in Fig. 1. The leading edge of the model is made

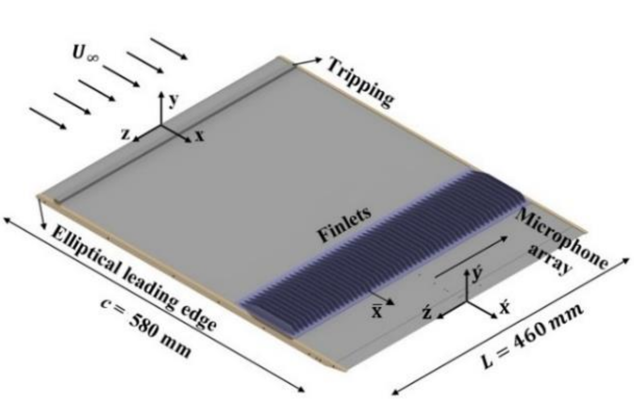

Fig. 1. Schematic view of the model, trip position, array of microphones and finlets installed on the model [6]

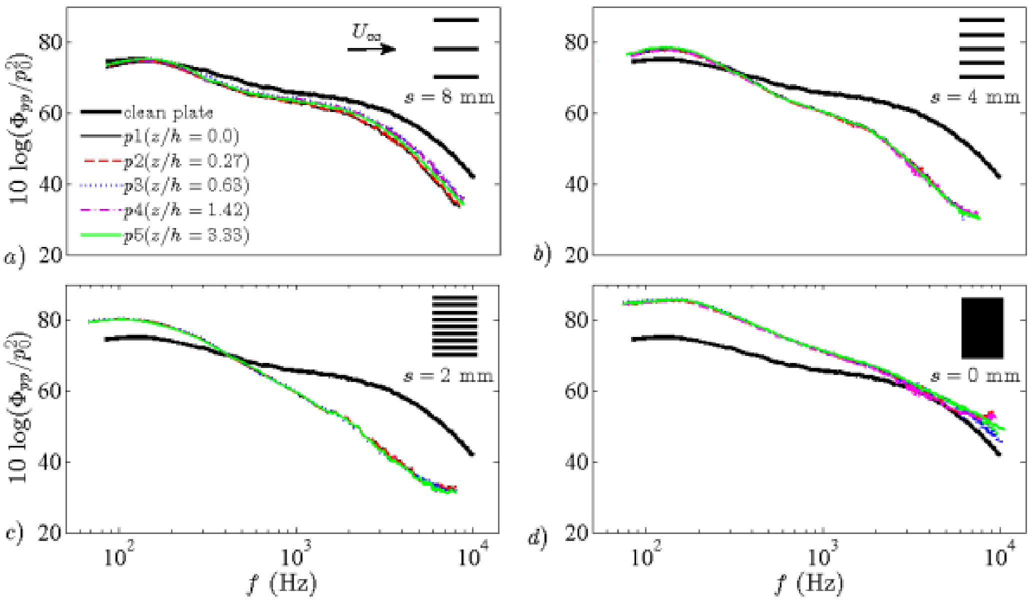

Fig. 2. Surface pressure spectra measured by microphones located in spanwise direction (p1-p5) for a) sample $s=8$) b) sample $s=4$, c) sample $s=2$, d) sample $s=0$ (Backward-facing step)

in an elliptical shape with a semi-major axis of 12 mm and a semi-minor axis of 4 mm. To measure the unsteady surface pressure, a total of nine miniature microphones (Knowles FG-23329-P07) are arranged in the form of an L-shaped array on the surface of the flat plate. To investigate the effects of finlets spacing, a total of four finlets with spacings of s=8; 4; 2 and 0 mm (solid section), with a height of h=12 mm, were fabricated using three-dimensional (3-D) rapid prototyping. The finlets are supported by thin substrates with a thickness of 0.5 mm, glued to the flat plate. The leading and trailing edges of the substrate are faired to the flat-plate surface by covering it with a 0.1 mm thick aluminum tape. The first part of the finlets follows the turbulent boundary layer profile, i.e. $\hat{x}^{4/5}$ ($\hat{x}$ begins from the finlets leading edge) to avoid sudden abrupt changes to the boundary layer. The finlets are placed on the top side of the plate, upstream of the trailing edge.

3- Results and Discussion

Using the pressure fluctuation signals measured simultaneously in the spanwise direction, the lateral coherence changes were evaluated and the spanwise length scale and the eddy convection velocity in the trailing-edge region were obtained. The presence of finlets causes the flow downstream of the finlets to be three-dimensional. To evaluate the finlet's efficiency in reducing the surface pressure spectra in different lateral positions, the results of the surface pressure spectra in spanwise direction (microphones p1 – p5) for different finlets are presented in Fig. 2. As can be seen, for the s=8, the presence of finlets generally leads to a significant reduction of the surface pressure over the mid to high frequencies, with no noticeable changes to the low-frequency energy content of the boundary layer. By reducing the spacing between the finlets to 4 mm (s=4), their effectiveness in reducing the surface pressure spectra at mid to high frequencies increases. For the s=2, the results demonstrate that, while the presence of finlets leads to a significant reduction in the pressure spectra at high frequencies, it also results in an undesirable increase in low to mid-frequencies.

Predicted turbulent boundary layer trailing-edge noise using the Amiet -Roger analytical model [9] at a vertical spacing from the trailing edge of the model is shown in Fig. 3. The difference between the trailing-edge noise in the presence and absence of finlets is presented in Fig. 3. Therefore, positive values indicate an increase in trailing-edge noise, and negative values indicate a decrease in trailing edge noise in the presence of finlets. According to Fig. 3, all finlets are found to be effective at mid to high

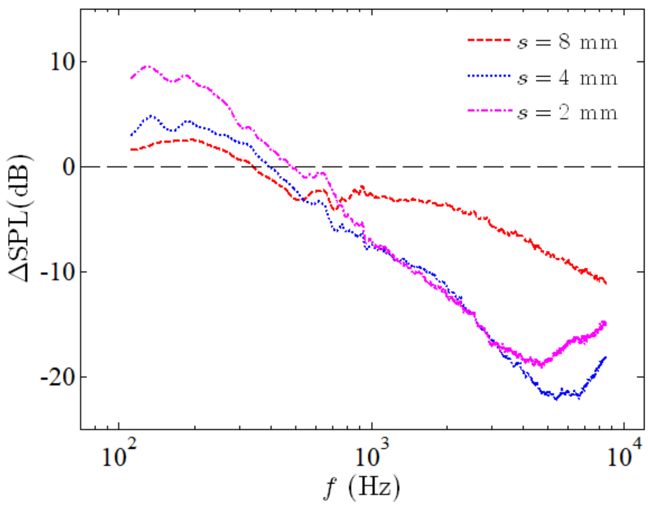

Fig. 3. Trailing edge noise predicted using the Amiet -Roger analytical model [7] in the vertical spacing of $y' = 1$ m

frequencies. However, the finlets appear to increase the trailing edge noise at the low frequencies. As can be seen, the use of coarse spacing (s=8) leads to a significant noise reduction at high frequencies (up to 10 dB) with an approximately 2 dB increase at low frequencies. For the finlets with fine spacing (s=2), these effects have been observed to intensify, that is, more increase at low frequencies (up to 8dB) and more reduction at high frequencies (up to 18 dB). The results also show that the case of s=4 is an optimal case so that despite the excellent performance at high frequencies, it has acceptable negative effects in the low frequency range.

4- Conclusions

In the present study, the trailing-edge noise reduction of a flat plate equipped with finlets was investigated. for this purpose, the effects of finlets on the main parameters determining the turbulent boundary layer trailing-edge noise including the surface pressure spectrum, the spanwise length scale of surface pressure fluctuations, and the eddy convection velocity in the trailing-edge region were investigated. The results showed that the flow behavior downstream of the finlets is strongly dependent on the finlet spacing. However, the far-field noise predicted by the Amiet-Roger model shows the effectiveness of all finlets in the mid and especially high frequency range.

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