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Influence of Slot Geometry on the Behavior of Synthetic Jets

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Extended Abstract

Synthetic jets have attracted considerable attention as alternatives to conventional continuous jets. It has been reported that the direction and jet structure of a two-dimensional planar jet can be tuned by its oscillation frequency, since the synthetic jets are oscillatory flows [1]. When controlling the jet direction using the oscillation frequency, the symmetry of the vortex pair is broken as the slot has an asymmetric beak or staircase shape, and the jet is considered to be deflected. In particular, it has been shown that there are cases where recirculation regions are generated near slots, and cases where staggered vortex rows in the form of inverse Kalman vortices are formed and deflected [2, 3]. Naturally, the deflection characteristics of a synthetic jet have been shown to depend on the asymmetric slot geometry. Although a number of reports have examined the behavior of synthetic jets generated by beak or staircase-shaped slots, no systematic studies have investigated the effect of slot geometry on synthetic jet behavior. The relationship between the flow characteristics and slot geometry remains unclear in many cases. It is therefore desirable to determine the optimal asymmetric slot geometry for jet angle adjustment.

This study aims to investigate the geometry and flow characteristics of a beak-shaped slot via numerical simulations and smoke-wire flow visualization experiments. In particular, the effect of the beak tip angle, β, on the flow characteristics of synthetic jets was investigated. The jet outlet slot width b_0 was 0.50 m, the slot height h was 0.10 m, and the aspect ratio was 20. The conditions in this study were as follows: the representative length was the slot width b_0, the representative speed U_0 was 3.0 m/s, the dimensionless stroke length L_0 was 10, and the dimensionless beak length, $C = c/b_0$, was approximately 3-12.

When $\beta = 11^{\circ}$, the alternating vortex trains moving downstream were barely entrained toward the slot outlet, and the deflection angle of the jet was small. Alternate vortex trains were generated at other beak tip angles. At $\beta = 63^{\circ}$, the vortex trains were entrained toward the slot outlet side, confirming the deflection of the jet. Furthermore, at $\beta = 79^{\circ}$, and $\beta = 90^{\circ}$, vortex recirculation was observed and the jet was deflected significantly. Hence, it was shown that when the dimensionless beak length $C \sim 3 - 12$, the jet was deflected to a greater extent when the beak tip angle β was increased. The closer the tip angle of the beak-shaped slot was to the 90°, the closer the slot resembled a staircase-shaped asymmetric slot. Therefore, a vortex did not develop at the top of the beak-shaped slot and the jet may have recirculated.

References

[1] Kobayashi, R., Nishibe, K., Watabe, Y., Sato, K., and Yokota, K., 2018, "Vector Control of Synthetic Jets Using an Asymmetric Slot" ASME *J. Fluids Eng.*, 140(5), p. 051102.
[2] Kobayashi, R., Nishibe, K., Yokota, K., and Sato, K., 2018, "Observation of Synthetic Jet Behavior in Asymmetric Flow Field" The 67th General Assembly Lecture of the Tokai Branch of the Japan Society of Mechanical Engineers. https://doi.org/10.1299/jsmetokai.2018.67.326.
[3] Ito, T., Nishibe, K., Donghyuk K., Sato, K., "Influence of the protrusion length on the synthetic jets produced by asymmetric slot" The Japan Society of Mechanical Engineers 2021, No. 21-1.