

Flow Regime Characterization of Jet Flow Controlled By Suction Slot on the Coanda Surface

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Extended Abstract

Jet direction control is expected to find applications in various fields. It started with research aimed at aircraft attitude control and has recently been put to practical use as e.g. vectoring nozzles. However, vectoring nozzles for thrust jets in aircraft have encountered problems such as hot exhaust gases, etc. Vashistha et al. point out that the effect of thermal deformation of the thrust nozzle on the thrust vector is greater than that due to pressure [1]. The advantages of methods with a large moving range have also been recognised in air-conditioning systems: Kajiya et al. tested movable air outlets in an air-conditioning system for a large interior space. Simulations confirmed the advantages over fixed ones, such as efficient cooling of the occupied area and elimination of stagnant areas of airflow [2]. Mechanical thrust vectoring using these structural geometrical changes has been validated in a wide range of fields. However, this method has many issues that need to be resolved in terms of complexity and cost in high temperature conditions and in the application to large control mechanisms.

A number of previous studies have examined fluidic thrust vectoring; Xue et al. validated a fluid vectoring technique with secondary flow and Coanda surfaces for aircraft [3]. They found that the jet deflection technique using a nozzle geometry with Coanda surfaces and secondary flow slots is capable of deflecting 18.80 (deg) not only at ground level but also at high altitude. This enabled the jet thrust to be deployed in the lateral direction as well. Recently, a method has been proposed to further improve jet deflection performance, whereby the jet is deflected by suction from a slot on a Coanda surface located near the primary jet. Nakagawa et al [4] and Suzuki et al [5] reported that the deflection angle of the jet can be increased to about 170 degrees by applying suction from several slots arranged on the Coanda surface. However, the characteristics of each suction slot have only been verified piecemeal, such as constant suction flow velocity, and there is little discussion on the optimum angle of the first slot.

This study is a fundamental study of jet vectoring by suction on a Coanda surface near the primary jet. Here, this study is carried out to optimise the jet control mechanism with slots on the Coanda surface. The slot width for the primary jet $h_1 = 1.0 \times 10^{-2}$ m and $U_1 = 5$ m/s is used for continuous jet. The suction slot width is $h_2 = 2.0 \times 10^{-3}$ and the slot holes are spaced at $\beta = 15$ (deg) on a Coanda surface of radius $R = 3.5 \times 10^{-2}$ m. In the verification, the number of slots on the Coanda surface was limited to one and the other slots were blocked. This allowed a constant slot width to be verified. The flow ratio $Q_2/Q_1 = 0.1, 0.2, 0.3, 0.4, 0.5$ was used to verify the influence of the flow ratio and the suction slot position β . Two-dimensional numerical calculations were used for the verification.

The numerical calculation results obtained in this study are shown below. However, the values representing the deflection angle are approximate values. At a slot position $\beta = 30$ deg with a flow ratio $Q_2/Q_1 \geq 0.1$ and at $\beta = 60$ (deg) with a flow ratio $Q_2/Q_1 \geq 0.3$. This confirmed the flow rate at which deflection started at each slot position. Under a slot position angle of $\beta = 30$ (deg), the deflection angle of the jet flow was $\theta_c \approx 51$ (deg) when the flow ratio $Q_2/Q_1 = 0.1$ and $\theta_c \approx 57$ (deg) when $Q_2/Q_1 = 0.3$. On the other hand, at $\beta = 60$ (deg), $Q_2/Q_1 = 0.3$ was $\theta_c \approx 81$ (deg). It was confirmed that the deflection angle of the jet changed significantly depending on the slot position.

The relationship between the suction flow rate and jet deflection characteristics at single slots at various angles on the Coanda surface was discussed in this study. It was confirmed that the larger the slot position angle β , the greater the suction flow required to align the jet along the Coanda surface. On the other hand, it was confirmed that the deflection angle θ_c

increases with increasing suction flow rate and slot position angle. In addition, it was found that the deflection angle θ_c increased with increasing slot angle β above the required suction flow rate ratio.

References

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