Study on the Fluidic Thrust Vector Control Using Co-Flow Concept

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ABSTRACT

In the present, various methods have been employed to obtain the lesser thrust loss. Numerical simulations have been carried out for optimizing the thrust vector control system. Thrust vector control based on coflowing shear layer is an effective method to control the primary jet direction in the absence of moving parts. Thrust vector in symmetric nozzles is acquired by secondary flow injections that result to boundary layer separation. The pressure in secondary flow inlet was varied to check the deflection angle of jet flow.

Key Words: Deflection angle, Supersonic flow, Shock wave, Boundary layer separation

1. Introduction

Over the past several decades, the benefits of fluidic thrust vector control in high performance were well established. Thrust vector control is a valuable topic to afford lots of benefits in the aspect of moving manoeuvrability and control effectiveness [1-2]. Thrust vector can allow the aircraft to take off and land on short distance. Various methods have been applied to control the deflection direction of primary jet. Some methods for thrust vector control include shock vector control, dual-throat nozzle control, throat-shifting control, co-flow vector control. The thrust vector technology, co-flow and counter-flow thrust vector control has been explored with promising results [3-4]. In addition, it can also be applied to maintain control effect under stalled conditions, thus improving the overall performance [5-6]. The shock vector control utilizes the shock wave to control the thrust direction but often reduces thrust ratio [7-8]. The dual-throat nozzle control method can provide higher thrust coefficient but the vector angle produced by per unit secondary flow is smaller [9].

2. Computational Model

1. Physical model

The study was conducted to testify the effect of the co-flowing and countercurrent shear layers on the performance of the thrust

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vector control. As shown in Fig. 1, the two-dimension nozzle geometry details focused in the paper was presented. The study was conducted at a design Mach number of 1.5, an expansion ratio of 1.173. The design nozzle pressure ratio (NPRD) is 3.67. Two secondary flow ducts need to be established above and below the nozzle to achieve the thrust vector control, each having a slot height approximately 40.9% of the primary nozzle exit height. The other collar geometry parameters were fixed, L/H=3.55, R/H=7.6.

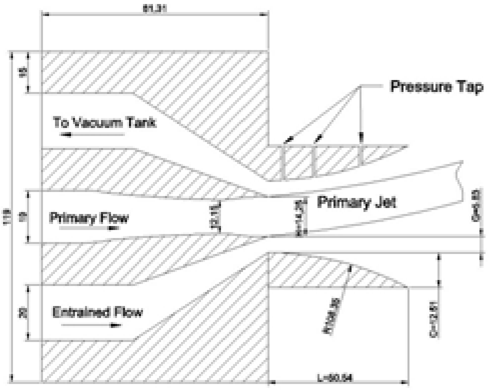


Fig. 1 Physical model

3. Results and Discussion

The simulation results for thrust vector angle are presented in Fig. 2 and compared with the ideal deflection angle value. There is a good match between the simulation and theory under different NPRp value. It can be observed that for the fixed NPRs value, the increase of NPRp value would produce a decreased thrust vector angle. However, the primary flow will attach on both suction collars when the NPRp increase continually.

As seen in the Fig. 3, secondary weight flow rates were obtained over a range of NPRp and the streamlines presented that all the cases were coflow. Although Ws/Wp is relatively low in the present NPRp values, further observations can discover that the thrust vector control would be more excellent if the NPRp value is very appropriate. Apparently, the simulation had the relatively lower secondary weight flow rates when the NPRp value was close to NPRd. For the case of NPRp=3, the thrust vector efficiency is highest. The efficiency decreases sharply with the increase of the NPRp under the underexpanded state.

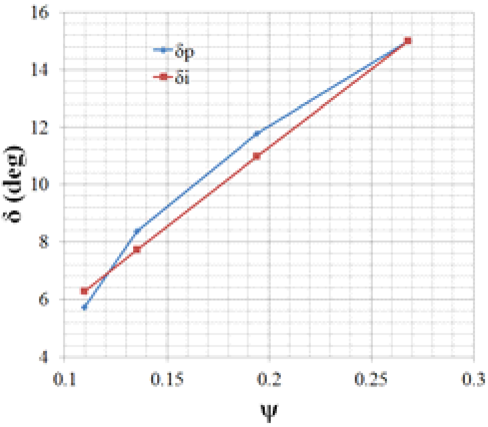
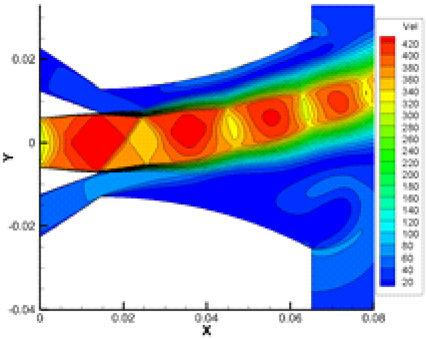


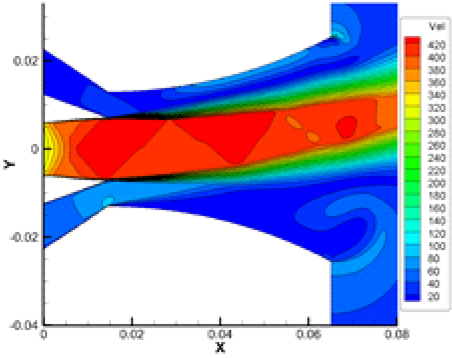
Fig. 2 Thrust vector angle

4. Conclusions

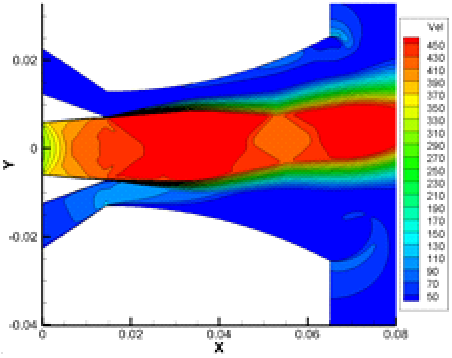
The simulations of co-flow thrust vector have been conducted in this paper. For validating the ability of the model, computational results were compared with the theoretical and experimental results. In general, pressure distribution was in good match with experimental result. The Mach number contours under the different NPRp values were presented. The thrust vector efficiency is highest and the secondary weight flow ratio is lowest at the NPRp=3. The current result furnished a significant method that increasing the NPRp within a reasonable range can address the jet attachment behavior.



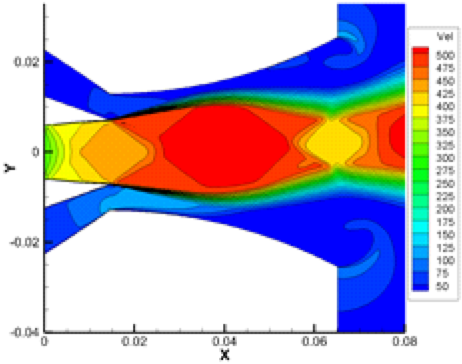
(a) NPRp=2



(b) NPRp=3



(c) NPRp=4



(d) NPRp=5

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