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Fundamental Numerical Study on Shock Wave Boundary Layer Interaction Control for Hypersonic Intake at High Altitude

高高度を飛行する極超音速機インテークのための衝撃波-境界層干渉制御に関する数
值的基礎研究

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Hypersonic vehicle is getting more interest in recent decades because of advanced technology and increase in demand. However, scramjet engine onboard the aircraft has negative impact to the ozone layer. In order to prevent such negative effect, it is advised that the vehicle should cruise at a higher altitude. Even though cruising at higher altitude can protect the environment, it also can result in a decrease in engine efficiency due to the effect of Shock Wave Boundary Layer Interaction (SWBLI). This study first tried to understand the effect of inlet performance when cruising at high altitude and the result will be used as a base model by using computational fluid dynamics (CFD) with the compressible Navier-Stokes analysis. Then a SWBLI control system is analysis and compared to the base model.

SWBLI occurred when a shock wave impinges into a surface where there is boundary layer. This create an adverse pressure gradient at the bottom layer as the presence of separation bubble. The presence of SWBLI can result in increased aerodynamic drag and heating, flow unsteadiness, reduction in engine performance. Therefore, it is necessary to apply control system to solve this issue. Suction, injection and hybrid system (include both suction and injection) are used as the SWBLI control system in current study. In addition, this research focus on scramjet inlet performance at a cruising altitude of 50km, total pressure recovery (TPR) and flow distortion (FD) are the two key parameters for evaluation.

Current study found that the use of injection only does not provide any positive result to the inlet performance, while suction and hybrid found to bring improvement. Moreover, hybrid case has the highest increase in TPR of 6.31% compare to the base model (50km) in current problem setting. This improve in inlet performance is even better than the lower altitude base model (40km). It also found that though the inject alone has negative impact, the extra air mass injected into the flow field would allow a stronger suction and thus result in an overall better inlet performance.