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Experimental and numerical investigation of smooth turbine-based combined-cycle inlet mode transition

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Abstract: Smooth transition from turbojet to ramjet mode is critical to turbine-based combined-cycle (TBCC) propulsion system. Wind tunnel tests and numerical simulation were conducted to investigate the method of smooth inlet mode transition, and acquire corresponding inlet flow details. Steady-state pressure distribution was recorded in the experiment to evaluate inlet performance. Combined experimental and numerical investigation results indicate that smooth inlet mode transition can be achieved by keeping the total throttle ratio of the TBCC inlet constant. When the total throttle ratio is equal to 56%, the Mach number and the flow ratio of aerodynamic interface plane (AIP) would be basically equal to 0.22 and 0.50, respectively. Meanwhile, the terminal shock wave is located near the throat of the inlet during the mode transition. This paper puts forward the method of smooth mode transition of tandem-type turbine-based combined-cycle inlet and provides the flow details during this process.

Keywords: Air-breathing hypersonic propulsion system; Turbine-based combined-cycle; Inlet mode transition; Wind tunnel test

Nomenclature

π	pressure ratio
σ	total pressure recovery
ϕ	mass flow ratio
A	area of inlet specific plane
$\dot{m}$	mass flow rate
Ma	Mach number
P^*	total pressure
T^*	total temperature
TR	throttle ratio
AIP	aerodynamic interface plane
TBCC	turbine-based combined-cycle
Subscript	
∞	free stream station
e	exit of the diffuser plane
t	throat station

1. Introduction

Hypersonic vehicle has draw-ever increasing attention in the world [1-3], for it could operate over a wide flight envelope at a speed of Mach 0-5 within an altitude between 0 and 30km. Nowadays, turbojet engine is able to operate below Mach 3. Meanwhile, ramjet can operate at a speed of Mach 3-5 or even higher. Consequently, the combination of these two engines can help realize this hypersonic flight. Turbine-based combined-cycle is the combination of turbojet and ramjet engines. This combined-cycle propulsion system has two fundamental advantages[4-5]. Firstly, this propulsion system absorbs the oxygen in the atmosphere. Compared with rocket-based combined-cycle the total take-off weight is reduced. Secondly, the hypersonic vehicles can take off and land horizontally with this propulsion system, which is helpful to improve the safety of the whole system. According to its configurations, the TBCC propulsion system can be divided into tandem type and over/under type. In this research, tandem-type TBCC inlet was investigated. The switching procedure between the two engines is called the

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