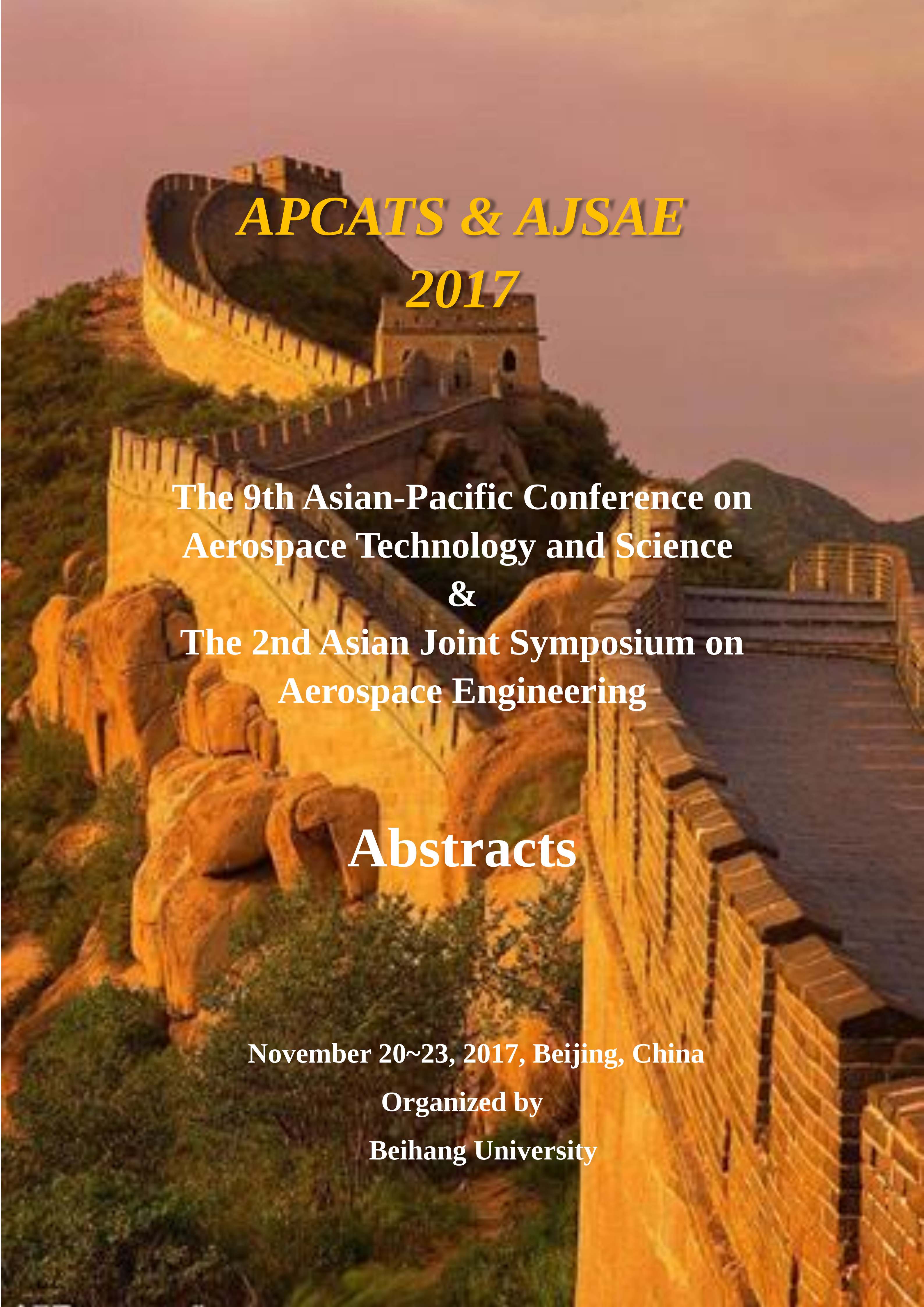

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&
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Abstracts

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Beihang University

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Analysis of Boundary Layer Ingestion on Aerodynamic Characteristics under cruise conditions

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Boundary layer ingestion (BLI) is the most noteworthy feature of the novel distributed propulsion configuration (DPC). Close coupling effects can be generated between engines and aircraft due to BLI and then lead to the specific aerodynamic characteristics. To investigate the unique aerodynamics, a new comprehensive analysis method is proposed in this paper. This method uses a synthetic computational model to analyze the aerodynamic characteristics with BLI effect, and the effectiveness of this method is validated by the results of computational fluid dynamics. After that, detailed analyses of BLI influences on aerodynamics are conducted at different cruise conditions, and the results reveal that BLI has extraordinary ability to improve the aircraft performance.

Keywords: Distributed propulsion configuration, Boundary layer ingestion, Aerodynamics, Cruise

1. Introduction

Distributed propulsion configuration (DPC) is a novel design for civil aircraft that not only improves fuel efficiency but also reduces pollution emission [1,2]. Compared to the traditional blended-wing-body layout, the semi-embedded distributed propulsion system of DPC features the effect of boundary layer ingestion (BLI). With BLI effect, the propulsion's performance is improved by the slower incoming airflow, and the aerodynamic performance of DPC is likewise significantly improved by ingesting the boundary layer flow on the upper fuselage surface. However, BLI effect makes the aerodynamic characteristics of DPC more complicated as well. Recent years have seen significant advances in the field of BLI effect, including the assessment of BLI effect on the engine's performance and aerodynamics [3-6]. Plas discovered the distortion transfer across the fan played a major role in determining the impact of BLI on fuel burn, and found that fuel burn can be decreased by 3.8 percent because of BLI [3]. Kok et al. found that a small number of BLI engines was a better approach that may not suffer high internal losses [4]. Mantic Lugo et al. investigated the effects of BLI on aerodynamics of a transonic wing, as well as the quality of the flow ingested by the propulsion system [5]. Kang et al. also conducted a preliminary 2D study on the aerodynamic characteristics with different BLI effects, which used a simplified sectional model to analyze the BLI influences on the lift and drag aerodynamic characteristics [6]. These studies conducted the preliminary research on BLI effect, however, to investigate the unique aerodynamic feature of the new configuration, detailed and precise analysis of BLI effects on aerodynamics are strongly needed.

Aiming at this problem, this paper gives insight into the specific aerodynamic characteristics with BLI effect under cruise conditions. A synthetic 3D computational model is built to analyze the influences of BLI on aerodynamics, and detailed CFD computations are carried out to reveal the features of BLI effect at different representative cruise states.

2. Description of the comprehensive analysis method

A typical DPC type called SAX-40 is selected as the research object. To accurately investigate the effects of BLI on aerodynamics, a comprehensive analysis method based on 3D computational model is proposed. As shown in Fig.1, this method is composed of three major parts: (1) shape models, including the fuselage and distributed engines, which can simulate the BLI effect in the CFD environment; (2) the DPS model, which provides the essential boundary conditions of engine inlet and outlet in CFD computations; and (3) CFD computations and analysis.

First, the 3D shape construction including SAX-40 fuselage and distributed engines is built in CFD environment, which is illustrated in Fig.2. Different engine's inlet and outlet parameters can correspondingly represent different BLI effect. The inlet and outlet boundary conditions are set as the flow entrance and the velocity exit. The boundary conditions contain engine's inflow parameters including the static temperature T_1, the static pressure P_1, the air flow rate q_m, as well as engine's outflow parameters including the static temperature T_8, the static pressure P_8, and the jet velocity V_8. These boundary parameters can be calculated by the DPS model in [6]. By changing these feature parameters, different BLI effect can be simulated and then its effect on the aerodynamic characteristics can be calculated by CFD.

Based on the 3D computational model, the BLI effect under cruise conditions and its direct influences on the aerodynamic characteristics are investigated. Typical flight states H=10000m, Ma=0.6 are selected to conduct a preliminary research on BLI effect. Fig. 3 shows the velocity and pressure plots of the DPC aircraft with different BLI intensities, respectively.

3. Conclusion

This paper conducts a systematic research on the unique aerodynamics of DPC aircraft influenced by BLI. A comprehensive analysis method is proposed, and a synthetic 3D computational model is built to accurately investigate the influences of BLI on the aerodynamic characteristics. Then detailed analysis of BLI effects on aerodynamics under cruise conditions is carried out. Computational results demonstrate that BLI can raise lift to drag ratio evidently and enable a great performance potentiality.

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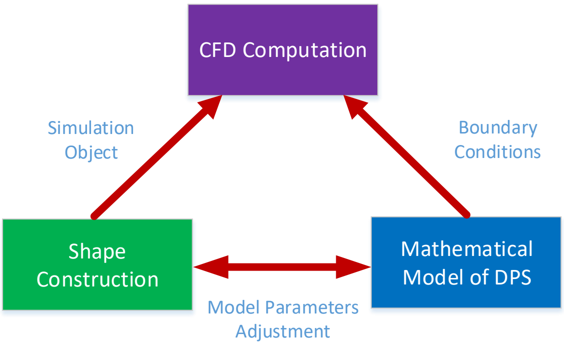


Fig. 14 Overall scheme of the analysis method.

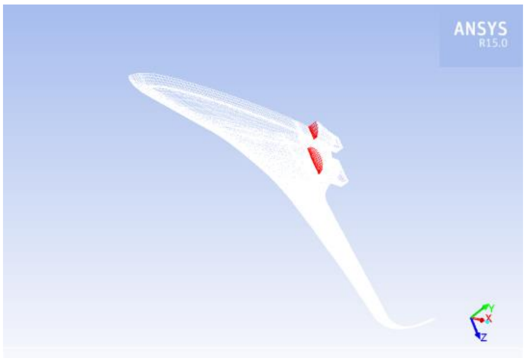
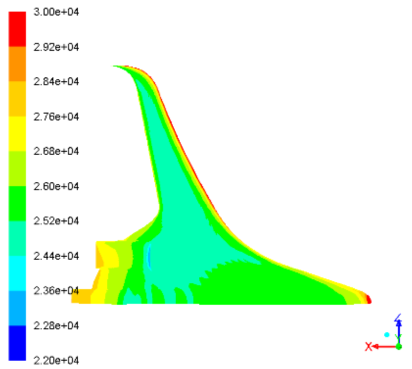
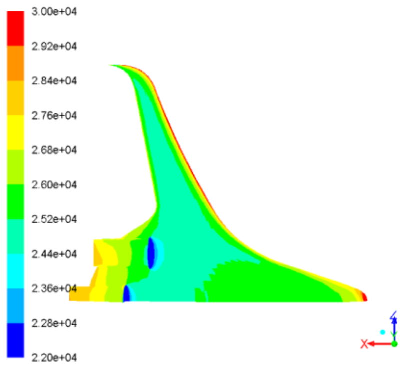


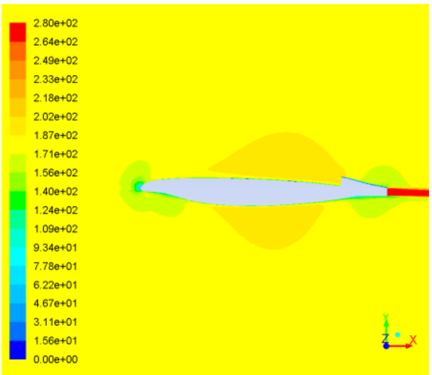
Fig. 15 3D shape construction.



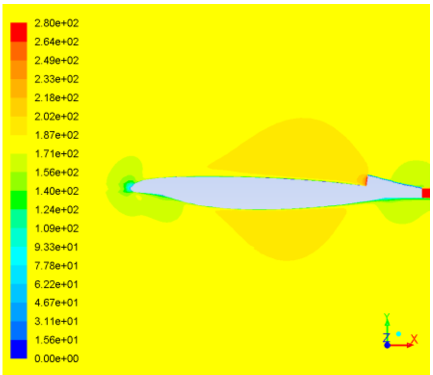
(a) pressure plot, pascal, low BLI intensity



(b) pressure plot, pascal, high BLI intensity



(c) velocity plot, m/s, low BLI intensity



(d) velocity plot, m/s, high BLI intensity

Fig. 16 Velocity and pressure plots