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Operation Matching Model and Analysis between an Air Inlet and a Compressor in an Air Turbo Rocket

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Abstract: Operation matching between an air inlet and a compressor in an Air Turbo Rocket (ATR) is crucial to the full development of the advantages of engines. In this study, operation characteristic models of an air inlet and a compressor were established and verified through numerical simulation to gain the matched operation characteristics of the air inlet and the compressor in an ATR. The air inlet–compressor matching model was constructed on the basis of coupling relations, such as "flow equilibrium," "interface parameter equilibrium," and "pressure ratio equilibrium," between the air inlet and the compressor in the ATR. Finally, the integrated 3D numerical simulation of the air inlet–compressor was verified. Results demonstrate that (1) the operation characteristic model of the air inlet can accurately calculate the effects of backpressure in the air inlet (P_b) on the total pressure recovery coefficients of the throat, the supersonic diffuser, and the whole air inlet in the ATR. Model prediction results are highly accurate as confirmed by 3D numerical simulation results in the following ranges: $2.75 < Ma < 3.75$ and $0.5\ atm < P_b < 3$ atm. The maximum absolute error is less than 0.05. (2) The centrifugal compressor model can indicate the airflow and performance parameters of different characteristic sectors of impeller entrance, compressor exit, and axial diffuser entrance and exit. The 3D numerical simulation reports that the maximum relative errors of static pressure, total pressure, and total temperature predictions are 13.25%, 11.30%, and 5.65%, respectively. (3) The constructed air inlet–compressor matching model can rapidly predict the airflow parameters and performance parameters of their characteristic sections under specific operation conditions. The "most stable operation curve" introduced in the pressure ratio characteristic curve of the compressor can quickly and accurately accomplish the initialization of matching iterative computations, thereby solving aerodynamic coupling problems on an air inlet–compressor interface. (4) The integrated 3D numerical simulation of the air inlet/compressor reveals that the relative errors of 17 in 18 airflow parameters of two components are lower than 8%, and the relative error of the other parameters is 10.91%. The model exhibits high accuracy and can satisfy the requirements for the performance prediction of air inlet systems in ATR.

Keywords: Air Turbo Rocket (ATR); air inlet; compressor; performance prediction model; operation matching