The impact of high-order numerical schemes on flow separation capturing of a linear compressor cascade using DDES method

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ABSTRACT

Delayed Detached Eddy Simulation (DDES) has been considered as a promising simulation method to calculate the massive flow separation, because it appears to be a suitable compromise between the physical models of turbulence and computational resource. DDES method has been used in aircraft simulation successfully, while still immature in internal flow field due to complexity. One of the vital factors to consider is numerical scheme. The requirement for DDES numerical schemes should be as stringent as Large Eddy Simulation (LES) since the majority of the field with the large vortex structure of separation is resolved by LES, or else, small-scale vortex structure in massive separation region cannot be captured accurately. So that it is very important to select the suitable schemes for DDES method aimed at flow separation capturing.

This paper aims at studying the effects of three numerical schemes on the calculation of flow separation in internal flow field using DDES method, to act as a guide for selecting high-precision numerical schemes with suitable resolution and acceptable computation cost. The linear compressor cascade used in the paper is based on a controlled diffusion airfoil (CDA) as shown in Figure 1. The investigation is conducted using DDES method based on Spalart-Allmaras model. Three different numerical schemes for convection term have been tested: Low Diffusion E-CUSP (LDE) scheme + 3rd order MUSCL scheme, 4th order central difference scheme and LDE scheme + 5th order WENO scheme. 2nd order central difference scheme is also used just for comparison. Explicit fourth-order Runge-Kutta scheme is taken as the temporal differentiation. To investigate the behavior of spatial discretization schemes in different condition, design and off-design condition are carried out respectively.

This study obtains multiple unsteady flow field data. The complex flow phenomena including corner separation and wake are analyzed in detail under high incidence angle condition using different numerical schemes. The results show that high-order and low-dissipation scheme is
necessary to calculate the small scale structures. The central difference schemes (2\textsuperscript{nd} and 4\textsuperscript{th} order center difference) are hard to match the precision of DDES method because of their high dissipation and strong empiricism; low dissipation scheme LDE can effectively reduce numerical dissipation, but the 3\textsuperscript{rd} order MUSCL interpolation stability is worse, and its recognition capability for eddy cannot be comparable to 5\textsuperscript{th} order WENO scheme.

![Figure 1: 3D drawing of cascade](image1)

(a) Fourth-order central difference  \hspace{1cm} (b) LDE + Fifth-order WENO

![Figure 2: Entropy distribution in mid span](image2)

**Key words:** DDES, flow separation, numerical schemes, internal flow

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