Fast implication of divergence correction for volumetric PIV data

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HIGHLIGHTS

• A weighted divergence correction scheme is proposed to reduce biased measurement errors on the three velocity components.
• A fast algorithm is developed to implement the divergence correction or weighted divergence correction.
• Numerical test on DNS data validates the high efficiency and accuracy for the fast algorithm and also shows the advantage of weighted divergence scheme over the traditional divergence correction method.

ABSTRACT

Forcing the experimental volumetric velocity fields to satisfy the mass conversation has been proved beneficial for improving the quality of the measurement data. A lot of correction methods including divergence correction scheme (DCS) have been proposed to remove the divergence errors of measurement velocity fields. For tomographic particle image velocimetry (TPIV) data, the measurement uncertainty for the velocity component along the light thickness direction is typically much larger than the other two components. Such biased measurement errors would weaken the performance of traditional correction methods.

The paper proposes a variant for existing DCS by adding weight parameters on three velocity components. The weighted DCS (WDCS) has strong advantages on correcting velocity components with different biased noise levels. Furthermore, a fast algorithm for DCS or WDCS is developed, making the correction process significantly low-cost to implement. The fast algorithm firstly decomposes the three-dimensional divergence operator into three one-dimensional derivative operators. Eigenvalue decompositions are subsequently made to facilitate the inverse operations on these derivative operators. At last, the correction velocity could be calculated by a series of simple equations, which is highly efficient. A numerical test on direct numerical simulation (DNS) data is performed to validate the accuracy and computational efficiency for the fast algorithm, and also to reveal the advantage of WDCS. It shows that for a typical 100×100×20 velocity fields, the correction time is about 0.1 seconds, faster than most of the existing correction methods. In the test of biased noise, the WDCS improves the error reduction percentages for all the velocity components by about 7 percentages compared to original DCS method, which is a promising result. Based on these results, the author suggests that the WDCS should become a routine procedure for TPIV data process.