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Validation of a newly developed divergence-free high-resolution MHD code against magnetic reconnection related problems

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Understanding the physics of unsteady turbulent magnetic reconnection phenomena in compressible flows is of significant interest in a wide range of space plasma sciences. Early computational works for such turbulent magnetic reconnection flows were dedicated to use a conventional approximate Riemann-type solver, and thus are often too dissipative to resolve the broad range of scales of MHD turbulence and the resultant reconnection phenomena. As a result, the prior simulations employed an anomalous resistivity with some tuned parameters to generate active magnetic reconnection, and they also concluded that at least Hall MHD simulation is necessary to investigate the reconnection phenomena. However, we emphasize that these conclusions were drawn based on using a conventional low-order accurate numerical method. The whole point of our thinking is that if we could construct a physically-consistent high-order accurate numerical method within the MHD approximation, the high-order accurate MHD simulation could be possible to predict the physics of unsteady magnetic reconnection phenomena. We verified this idea by developing a physically-consistent high-order accurate numerical method for compressible MHD simulation and applying it to the problem of interaction of multiple magnetic islands in a long current sheet. The results showed that similar to the two-fluid simulation and PIC simulation the MHD simulation successfully predict the unsteady nature of the active magnetic reconnection phenomena such as X-lines movement and the growth of the magnetic island. The results demonstrate the importance of employing the physically-consistent high-order accurate numerical method for studying the magnetic reconnection phenomena. Furthermore, we think that this study could be extended to investigate the physics of turbulent (thus three-dimensional) magnetic reconnection and planetary formation phenomena.

Keywords: magnetic reconnection, MHD simulation