Commun. Comput. Phys.
doi: 10.4208/cicp.OA-2022-0224

Vol. **36**, No. 1, pp. 160-199
July 2024

Development of a Less Dissipative Interface Variable Reconstruction to Solve the Euler Equations by Q Learning Method

Shing-Ian Huang, Sheng Chang Wu, Tsung-Yu Yang, Chi-Heng Ting, Yi-Jhen Wu and Yang-Yao Niu*

Department of Aerospace Engineering, Tamkang University, New Taipei City, ROC.

Communicated by Kun Xu

Received 4 September 2022; Accepted (in revised version) 13 May 2023

Abstract. In this study, we propose a blend of the average of THINC-EM and MUSCL (ATM) methods based on the AUSMD scheme for solving detonation wave problems. It is well known that the simulation of the detonation problems can produce incorrect shock information or strong spurious due to the stiff source term. Accurate simulation of detonation problems plays a crucial role in the design of detonation engines. The proposed ATM method combines the MUSCL and THINC-EM methods with different weighting functions, the optimized parameters of which are determined by the Q-learning method in order to accurately capture detonation waves, shock waves, and expansion fans. To validate the proposed numerical method, one and two-dimensional shock tube and the detonation tube and nozzles are chosen as benchmark test cases. Our numerical results show that the proposed the ATM type AUSMD scheme has great potential for handling more complex detonation problems and pulse detonation engine flow problems.

AMS subject classifications: 65Y04

Key words: High resolution scheme, Euler equation, ATM method, discontinuity and detonation, Q-learning.

Nomenclature

U: Conservation term
E: Convection term of x axis
F: Convection term of y axis
ψ: Source term

*Corresponding author. *Email address:* yyniu@mail.tku.edu.tw (Y.-Y. Niu)

u: Velocity of x axis
v: Velocity of y axis
e_t: Energy
q_0: Chemical heat release
ρ: Density
p: Pressure
R: Gas constant
ε: Reaction time
r: Specific heat ratio
z: Fraction of unreacted fluid
T: Temperature
T_0: Ignition temperature
$\dot{m}$: Mass flow
h: Enthalpy per unit mass
Q: Q value
s_τ: Current state
a_τ: Current action
$s_{\tau+1}$: New state
$a_{\tau+1}$: All possible actions at that new stat
η: Learning rate
γ: Discount rate
r: Reward for taking that action at that state
τ: Time period

1 Introduction

As demonstrated by numerous studies, the thermodynamic cycle of the engine driven by a detonation wave is highly efficient [1–3]. During operation of detonation engines, the detonation wave, which propagates at supersonic speed, typically transforms reactants into products and releases energy, resulting in sudden and sharp jumps of the thermodynamic states. It is noted that under certain conditions, the detonation wave propagates at or near the Chapman-Jouguet (CJ) velocity, which is induced by the reactions associated with shock waves and expansion fans within ducts or nozzles. There is a wide spectrum of length scales and times in the collision of transverse waves caused by high pressure regions and intensive reactions. However, it is not easy to observe the process of detonation and understand the relevant scientific theories inside the internal reactive flows. Numerical simulation is often the most economical and effective way to study internal detonation flows. The hyperbolic conservation laws are generally used in conjunction with the stiff source terms to model the discontinuity fronts of the chemical reactive flows. However, traditional schemes may produce spurious or incorrect wave information due to inho-