THE 5TH ASIAN COMPUTATIONAL FLUID DYNAMICS
BUSAN, KOREA, OCTOBER 27 ~ 30, 2003

Performance of Two Different High-Accuracy Upwind Schemes in Inviscid Compressible Flow Fields

R. Hosseini[1], M.H. Rahimian[2], M. Mirzaei[3]
Mechanical Eng. Department, Faculty of Eng., University of Tehran, Tehran, Iran
1. MS student, e-mail: hoseinis@me.ut.ac.ir
2. Assistant Professor, e-mail: rahimyan@ut.ac.ir
3. Assistant Professor, e-mail: mirzaei_m@yahoo.com

Abstract

In this paper, performance of first, second and third order accurate methods for calculation of inviscid fluxes in fluid flow governing equations are investigated. Accuracy, convergence rate and shock capturing of these methods are discussed and advantages of each one are compared with those of the others. For this propose an upwind method based on Roe's scheme is applied to solve two-dimensional Euler equations. To increase the accuracy of this method two different schemes are used: The first one is a second and third order upwind-based algorithm with the MUSCL extrapolation van leer (1979), for the primitive variables pressure (p), velocity components (u,v) and temperature (T), in order to obtain the inner (L) and outer (R) flow conditions. The second one is upwind-based algorithm with the Chakravarthy extrapolation for the fluxes of mass, momentum and energy at the left (L) and the right (R) of interface. In the current computations, the Van Albada et. al. flux limiter(1982) and minmod slope-limiter is applied, respectively.
To show the reliability of the code, Mach number distribution along the bottom wall of the bump domain for 21x61, 31x91 and 51x151 grids are compared and grid independency of the code is achieved. To indicate performance of above schemes, two various test cases are analyzed: The first test case is a supersonic inviscid flow with M = 1.65 over a 4% bump and the second one is a supersonic flow with M = 2.0 over a 10-degree compression corner.
The results of these test cases are shown in Figs. 1 and 2. Fig.1-shows a 51x151 grids in physical domain. Fig. 1-b to 1-h indicates the pressure contours in the domain for first, second and third order accurate methods by using MUSCL and Chakravarthy extrapolation. The comparison of Figs 1-c, 1-d with Figs 1-e and 1-f, shows that the thickness of shock layer in the third order accurate is less than its value in second order. The comparison of Figs 1-e, with Fig. 1-g, represents that applying limiter eliminates the oscillations near the shock while causes the thickness of shock layer to increase in both methods. Of course, this increase in MUSCL scheme is noticeable but in Chakravarthy method is almost negligible.
Fig. 2, indicates the profile of Mach number on the lower wall of the duct with the same geometry. First, second and third order accuracies in the above methods are compared and this results in a highly conformity with those of literature. The profile of pressure coefficient at the lower wall of a compression corner is plotted in Fig. 6, by using Chakraverthy method with M = 2.0. It is observed that these results are well agreed with those of adaptive mesh refinement method[1]. It seems that, Chakravarthy method with and without limiter, in comparison with MUSCL scheme, not only can capture shock better, but also have a superior pressure and Mach number profile, in this Mach number limit.

Reference

[1] R. C. Ripley, F.-S. Lien, and M. M. Yovanovich, "Isotropic Mesh Adaption of Supersonic Channel Flows on Unstructured Meshes", Proceeding of CFD 2002 Conference, pp. 311-316, Windsor, Canada.

Paper No. : 2-2C-2

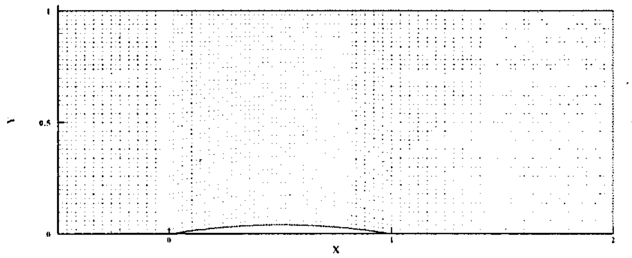

Fig. a- Grid configuration over a bump

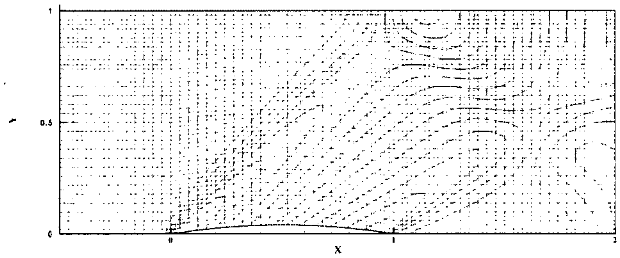

Fig. b- First order accurate

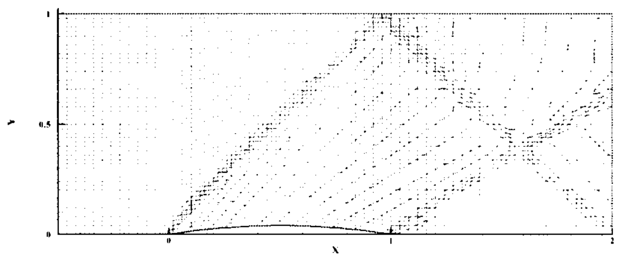

Fig. c- 2th order MUSCL without limiter

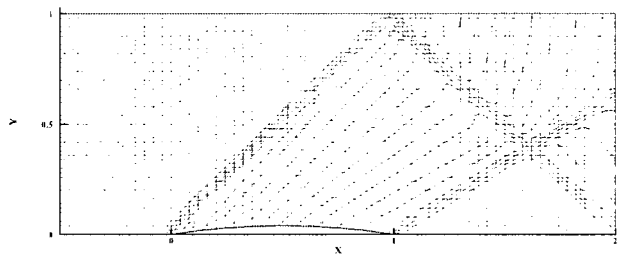

Fig. d- 2th order Chakravarthy without limiter

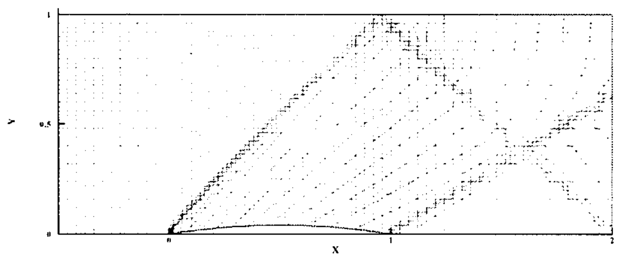

Fig. e- 3th order MUSCL without limiter

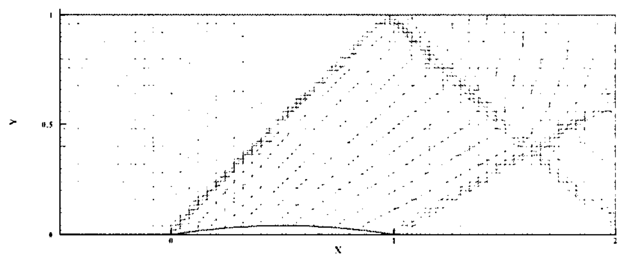

Fig. f- 3th order Chakravarthy without limiter

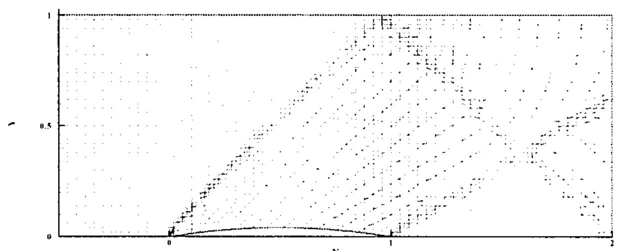

Fig. g- 3th order MUSCL with limiter

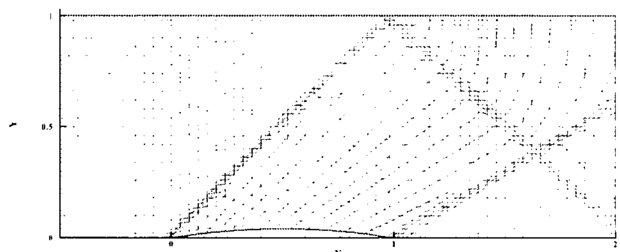

Fig. h- 3th order Chakravarthy with limiter

Fig. 1. Pressure contours of supersonic flow over a bump with free stream Mach = 1.65

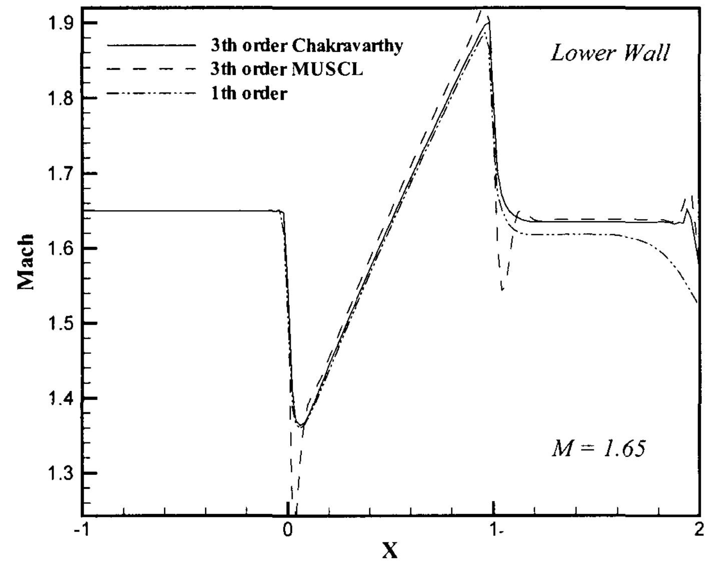

Fig. 2- Distribution of Mach number without limiter

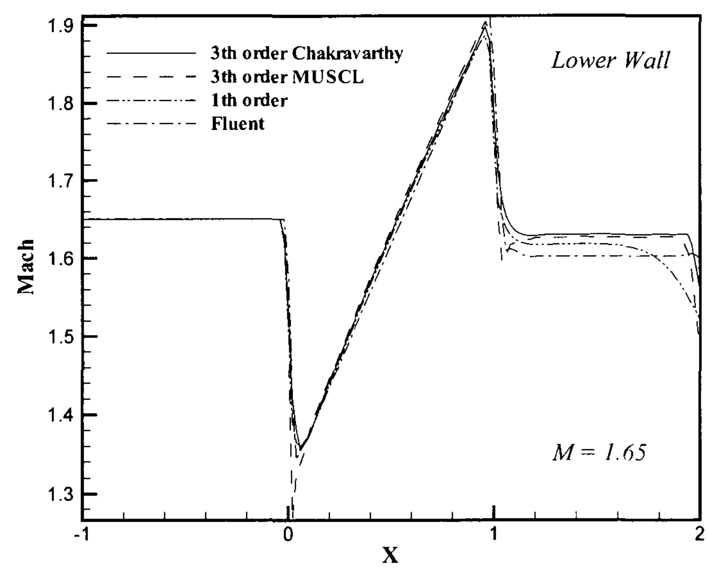

Fig. 3- Distribution of Mach number with limiter

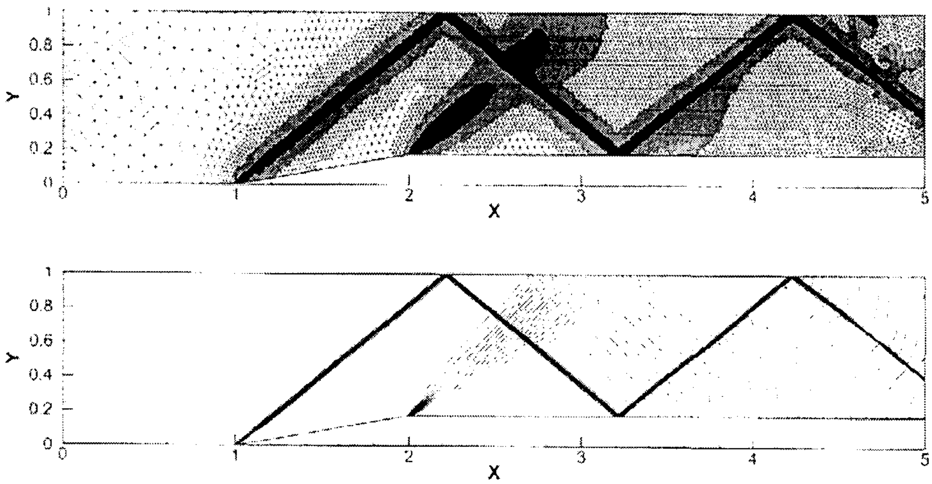

Fig. 4- Pressure contours in unstructured adaptive mesh refinement domain[1]

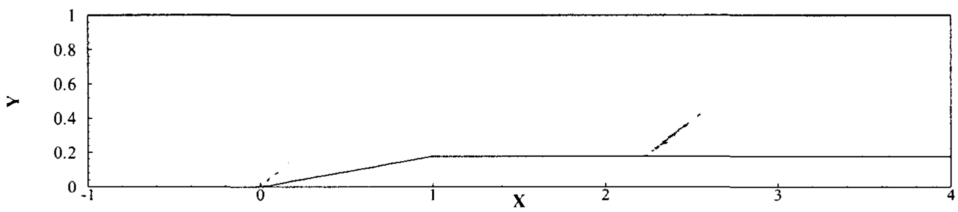

Fig. 5- Pressure contours with 3th order Chakravarthy method

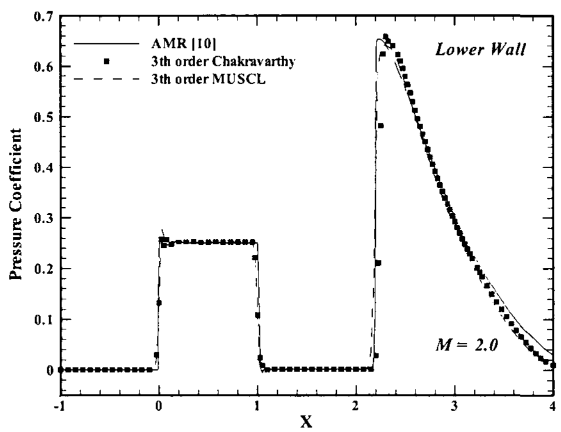

Fig. 6- Pressure distribution on the lower wall of compression corner