An Upwind Meshfree Method for the Supersonic Flow

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Abstract

Recently much attention has been drawn to meshfree method since conventional methods such as FDM, FVM and FEM have suffered from difficulty with mesh generation for complex geometry and deformable bodies. In this paper, an upwind point collocation meshfree method developed by the authors is applied to two shock wave diffraction problems. One is the shock diffraction over a 90-degree corner and the other is the single Mach reflection on a ramp. The scheme showed stability and the results showed accuracy.

***Keyword:** point collocation, meshfree methods, upwind, local stencil, hyperbolic equations*

1. Introduction

In contrast to the conventional methods that require a high quality mesh, the meshfree methods do not require any connectivity among the nodes but information on the nodal point coordinates. Hence it is inherently appropriate for complex flow geometry and bodies. Conventional schemes require constant re-meshing should there be discontinuity such as shock or crack, or should there arise large deformation. Now that the meshfree method does approximate a function using the coordinate information of the nodes, which are given without connectivity, nodes can be just added or removed (so called h-adaptivity) instead of re-meshing if control of local computational accuracy is necessary. It saves much time needed for excessive re-meshing.

Among many meshfree methods, Point Collocation Meshfree Method (PCMM) is chosen since it is simple and fast as well as it is regarded as a truly meshfree method. Until now, application of PCMM has been limited to elliptic and parabolic equations because there is no innate dissipation mechanism in these problems. In hyperbolic equations such as inviscid Burgers equation and Euler equations, the nonlinear convective terms play a decisive role in the stability of numerical methods. Calculation would fail if there is no dissipation mechanism. We developed a PCMM with innate dissipation that depends on particular flow situation, namely, the so-called upwind PCMM employing a local stencil approach (LSA) [1]. The key idea of LSA is that conservative variables are obtained by meshfree approximation on the auxiliary stencils, on which any FDM or FVM upwind scheme can be applied to calculate the convective terms. Shock propagation problems are solved to test future application of the scheme to the high speed compressible flows.

2. Shock Propagation Problems

2.1 Shock Diffraction Over a 90-Degree Corner

Calculation of moving shock and unsteady diffraction is tested here. The initial shock moves with Mach number M=1.5. Fig. 1 shows the computational result that is well compared with the experiment by Takayama and Inoue [2].

2.2 Single Mach Reflection on a Ramp

Mach number of the incident shock is 2.03 and the ramp angle is 27 degree. In Fig. 2, it is observed that the slip line dividing entropy difference region is formed. The experimental interferogram reported by Deschambault & Glass[3] is compared with the present result. The density contour and the density distribution along the wall surface agree well with each other, except the slip line is smeared in the case of the calculation.

3. Conclusions

We have successfully applied our Point Collocation Meshfree Method to the shock wave propagation problems. Such computation would have been almost impossible if the Galerkin-type meshfree method had been used due to the immense computational load. The present method is demonstrated to be simple, fast and accurate in comparison to other meshfree methods.

References

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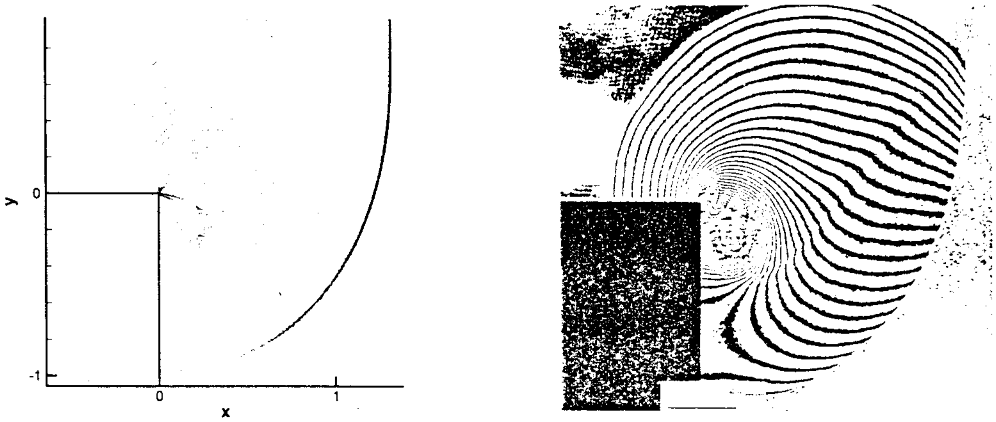
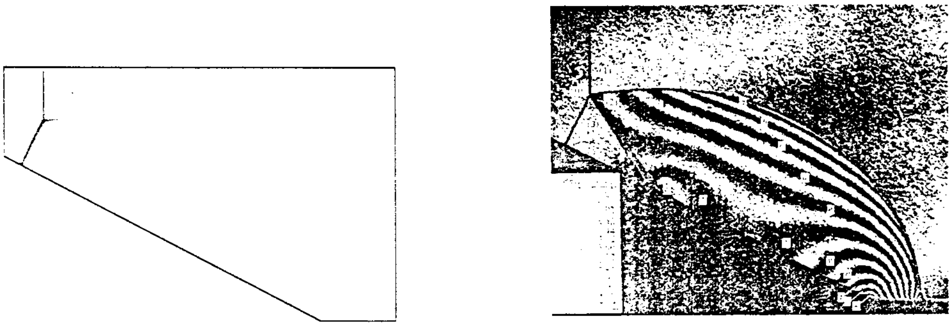


(a) density computation (b) experiment by Takayama & Watanabe

Fig. 1 Shock diffraction over 90 degree corner



(a) density computation (b) experiment by Deschambault & Glass

Fig. 2 Single Mach reflection on wedge