Quasigasdynamic system of equations and its' application to simulation of unsteady viscous flows

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ABSTRACT

Quasigasdynamic system of equations was obtained as a differential approach to original kinetic schemes [1]. For viscous flows description it can be written in the next form [2]

$$\frac{\rho^{i+1}-\rho^{i}}{\Delta t}+\nabla_i(\rho u^i)=\nabla_i\tau\nabla_l(\rho u^i u^l)+\nabla_i\tau\nabla^i p \tag{1}$$

$$\begin{aligned}&\frac{(\rho u^k)^{j+1}-(\rho u^k)^j}{\Delta t}+\nabla_i(\rho u^i u^k)+\nabla_i p=\nabla_i\tau\nabla_l(\rho u^i u^l u^k)+\\&+\nabla_i\tau\nabla^k(pu^i)+\nabla^k\tau\nabla_i(pu^i)+\nabla_i\tau\nabla^i(pu^k)\end{aligned} \tag{2}$$

$$\begin{aligned}&\frac{E^{j+1}-E^j}{\Delta t}+\nabla_i\left((E+p)u^i\right)=\nabla_i\tau\nabla_l u^i u^l(E+2p)+\\&+\nabla_i\tau\nabla^i\left(\frac{p}{\rho}(E+p)\right)\end{aligned} \tag{3}$$

The τ – time between collision of molecules.

The system (1)-(3) differs from classical Navier-Stokes equations on value $O(\tau^2)$ and give in numerical realisation practically the same results. But the quasigasdynamic systems is correct from physical point of view and guarantee the smoothing of solution on the distance of average free length path.

This fact correlated with the main physical topic on which based gasdynamic approach – the small difference between one particle distribution function f and local maxwellian function f_0

$$f \approx f_0 \tag{4}$$

From another side from expression (4) can obtained from the fact that one particle distribution function must have small variation on distance *l.* This strong nonlinear system (1)-(3) have invariantness on group of rotation and Galilean –transformation with accuracy $O(\tau^2)$.

Kinetic schemes quasigasdynamic system have very interesting correlation with popular and perspective advanced method – Lattice Boltzmann schemes [3] and stabilisation technique by E.Oñate [4].

Internal correctness and simple adaptation on architecture of massively by parallel computers give the opportunity of using quasigasdynamic system for simulation of complex flow of a viscous gas – turbulent and unsteady flow, acoustic and combustion phenomenon [5]. Some results of numerical simulation of this problem are discussed in the paper. It should be noted that using more and more fine grids provide practically the same flow patterns but usage of finest grids allow to resolve small flow structures and to obtaine a more wide spectrum of oscillations.

As example of numerical simulation there are discussed here the result of simulation of 3D unsteady

viscous flow near the cavity and simulation of 2D aeroelastity problem near the cavity with a flexible bottom. In both cases the oscillation take place only for concrete velocity of inlet flow and sizes of cavity. For simulation of 3D problem there used the 1TFLOPS – 768 processor computer system. The number of numerical nodes was equal $4 \cdot 10^7$.

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