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非定常不可压N-S方程的最小二乘算子分裂有限元法数值求解

Numerical solution for unsteady incompressible N-S equations by least-squares-based operator-splitting finite element method

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中文关键词: 最小二乘算子分裂有限元法 N-S方程 方腔流 圆柱绕流

英文关键词:least-squares-based operator-splitting finite element N-S equations driven square flow flow over a circular cylinder

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中文摘要:

采用最小二乘算子分裂有限元法求解非定常不可压N-S（Navier-Stokes）方程，即在每个时间层上采用算子分裂法将N-S方程分裂成扩散项和对流项，这样既能考虑对流占优特点又能顾及方程的扩散性质。扩散项是一个抛物型方程，时间离散采用向后差分格式，空间离散采用标准Galerkin有限元法。对流项的时间项采用后向差分格式，非线性部分用牛顿法进行线性化处理，再用最小二乘有限元法进行空间离散，得到对称正定的代数方程组系数矩阵。采用Re=1000的方腔流对该算法的有效性进行检验，表明其具有较高的精度，能够很好地捕捉流场中的涡结构。同时，对圆柱层流绕流进行了数值研究，通过流线图、压力场、阻力系数、升力系数及斯特劳哈数等结果的分析与对比，表明本文算法对于模拟圆柱层流绕流是准确和可靠的。

英文摘要:

A method for simulation of unsteady incompressible N-S(Navier-Stokes) equations is presented.In the each time step,the N-S equations are split into the diffusive part and the convective part by adopting the operator-splitting algorithm.For the diffusive equation,the temporal discretization is performed by the backward difference method and the spatial discretization is performed by the standard Galerkin method.For the convective equation,it is the first-order nonlinear partial differential equation;the temporal discretizaton is also performed by the backward difference method and Newton's method for the linearization of the nonlinear part.The spatial discretization is performed by the least square scheme and the resulting matrix is symmetric and positive definite.The driven square flow and flow over a circular cylinder are conducted to validate.Numerical results agree well with benchmark solution for the simulations of the driven square flow.Especially,for the flow over a circular cylinder,the numerical results such as the forces of cylinder,Strouhal number and the pressure on the cylinder surface agree well with experimental and numerical results,which prove that it can exactly and reliably to simulate the characteristics of flow over a circular cylinder in laminar flow.