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全附体潜艇粘性流场的RANS模拟及场量和涡量的校验分析

RANS simulation of viscous flow over full appended submarine and field variables validation and vortic analysis

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中文关键词： 潜艇 SUBOFF RANS模拟 粘性流场 场量 涡量

英文关键词:submarine SUBOFF RANS simulation viscous flow field variables vorticity

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中文摘要:

采用相同拓扑结构和相近网格质量的4套网格和5种湍流模型,对全附体Suboff 潜艇粘性流场进行RANS模拟,分析了网格密度、节点空间分布规律和湍流模型对计算精度的影响校验了其力积分量、速度场量和涡量特征。结果表明:网格密度最大的G4网格(140万)计算精度最高,总阻力较实验值误差为0.723%, 其采用SST湍流模型时最优。计算得到的压力系切应力系数分布均与实验值吻合很好;桨盘面速度等值线分布计算精度与文献相当, 轴向相对速度0.9以上的计算半径稍大于实验值,其余半径与实验吻合较好;桨盘面上0.25倍半径分量沿周向分布计算精度较文献高,轴向分量与实验值吻合较好,径向分量峰值稍小于实验值,但峰值所处周向位置与实验值一致。成功捕捉到了附体端面绕流诱导对旋涡、附体叶根下游处项链形涡对、尾翼端面尾缘上方附着涡蹄、附体马蹄涡系、尾翼截面通道流体挤压作用诱导涡以及桨盘面涡量汇集的潜艇涡量场特征,且围壳端面绕流诱导对旋涡沿流动方向稳定,不影响桨盘面涡量场,均与文献中由大涡模拟模拟得到的定性结论一致。研究表明,在网格密度较大、节点分布合理、网格质量较高、湍流模型选取适当和壁面函数使用有效的下,RANS模拟潜艇粘性流场的场量和涡量特征同样具有很高的计算精度,能够在工程应用中有力支撑新型艇型设计与性能分析。

英文摘要:

After RANS simulation of full appended SUBOFF submarine's viscous flow with four groups of grids of the same mesh block topology and close mesh quali five turbulent models,effects of mesh density and nodes distribution and turbulent models on calculation precision were analyzed,and detailed validation of integral variables and velocity field variables and vorticity of viscous flow were completed at last.Results show that G4 (1.4 million) with the most mesh d can get the highest precision,which calculated total drag just differ by 0.723% to the experiment.As for the G4 mesh,choosing the SST model in the calculati the best.Using G4,the predicted pressure coefficient and wall shear stress coefficient distribution both fit very well with the experiment; The numerical precision of the velocity profiles on propeller disk plane is near to the reference,and the calculated radial position for dimensional axial velocity over 0 a little bigger than the experiment,while the rest is good agreement with the data; The precision of the three velocity components at r/R=0.25 is higher tha reference too as a whole,and its axial component fits well with the experiment,the radial components' peak is a little lower while its circumferential posi is coincident with the measure.What's more important,RANS simulation of the G4 successfully captures the complexity vorticity structures,including counter- rotating vortex induced by flow over fairwater cap and stern fin's tip surface,necklace-shaped vortex pair downstream of the appendages' root section,shoe shaped vortex attached upwards of stern fin's tip surface trailing edge,horse-shoe vortex system induced by the flow around the appendages,vortex induced b extrusion within the passages of stern appendages,and the vortex concentration phenomenon on propeller disk plane,even the phenomenon of counter-rotating vo induced by flow over fairwater cap being stable along the streamwise and getting no effects on vorticity on propeller disk plane,which are all coincident wi numerical results completed by LES presented in reference.This paper shows that under the condition of refined mesh density,the nodes' reasonable distribution,good mesh quality,credible turbulent model and valid wall-function,the RANS simulation of full appended submarine's viscous flow can also get credible field variables and vorticity,so as to offer a powerful solution for the new submarine's design and performances prediction in marine engineering.

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