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基于本征正交分解和代理模型的流场预测方法

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Flow Field Estimation Method Based on Proper Orthogonal Decomposition and Surrogate Model

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摘要

为了实现流场的快速求解,基于本征正交分解(POD)与代理模型提出了一种全新的流场预测方法。其基本原理为:首先采用本征正交分解将一定数量的样本流场分解为同等数量的基模态流场;然后用少数包含了绝大部分样本流场特征的基模态流场拟合所有的样本流场;最后用代理模型建立起决定样本流场的输入参数与拟合系数之间的近似函数关系。针对几何外形不同的二维翼型定常流场预测结果表明:在亚声速情况下,预测误差收敛的模态数量不超过20个,继续增加模态的使用数量不能明显提高预测精度;在跨声速情况下,预测误差收敛的模态数量为26个,当使用的模态数量达到前10个时,继续增加模态的使用数量能提高绝大部分流场区域的预测精度,但同时会在激波附近引入"噪声"激波特征而降低该区域的局部预测精度。在这两种情况下,预测流场所需时间均不到高精度计算流体力学(CFD)方法的1/200。

关键词： 流场 预测 本征正交分解 代理模型 “噪声”激波特征 计算流体力学

Abstract:

To accelerate flow field calculation, a novel estimation method is proposed in this paper. The basic principle is: first, decompose a set of sample flow fields into the same number of basis mode flow fields. Then fit each sample flow field using a few of the basis mode flow fields which contain most characteristics of all samples. Finally, use a surrogate model to build the fitting function between the fit coefficients and the input parameters which decide the sample flow fields. The tests about the steady flow fields of airfoils whose shape are different from each other indicate that: under subsonic conditions, the estimation errors of both surrogate methods would converge with no more than 20 basis modes. Using more basis modes would not improve the estimation precision obviously. Under transonic conditions, estimation errors of both surrogate methods would converge when the number of basis modes is 26. Based on the first 10 modes, introducing more basis modes can improve the estimation precision in most areas of the flow field. But it would bring "noise" shock wave features to the area around the shock wave and decrease the predictive precision at that area. Under both conditions, the computational efficiency of this new estimation method is two hundred times better than the high precision computational fluid dynamics (CFD) method.

Keywords: flow field estimation proper orthogonal decomposition surrogate model noise shock wave feature computational fluid dynamics

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