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基于CFD的机翼突风响应计算

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CFD-based Analysis for Gust Response of Aircraft Wing

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摘要 利用网格速度理论,计算机翼在锐边突风和1-cos突风下的响应,研究气动非线性和自由度耦合对翼尖加速度和升力系数的影响。采用中心格式有限体积法进行空间离散,并用双时间推进法求解非定常Euler方程。计算了刚性(沉浮)和弹性机翼在锐边突风下的加速度响应,以及刚性机翼(沉浮+俯仰)在1-cos突风下的升力响应过程,并分别与片条理论和六自由度方程的计算结果比较。在低马赫数时,各种方法得到的结果符合得很好,直接验证了网格速度方法在三维弹性和刚性机翼突风响应计算中的准确性,为计算流体力学(CFD)技术在突风响应计算中的应用打下基础。从高马赫数时CFD计算得到的结果可以看出,气动非线性对于机翼突风响应的结果影响比较大,在实际突风响应计算中必须考虑由于非线性带来的影响,而六自由度方程中各个自由度的耦合作用对升力的影响不大。

关键词: 突风响应 片条理论 有限体积法 Euler方程 六自由度方程 弹性机翼 模态叠加法

Abstract: The grid speed method is used to calculate the sharp-edged and 1-cos gust response of wing configuration using computational fluid dynamics (CFD) tools. The spatial discretization of the Euler equations is performed using the central scheme, and time integration was implemented by the dual time-stepping approach. The sharp-edged gust response analysis of both rigid (plunge) and elastic wing configurations is performed, and the acceleration response is calculated and compared with the strip theory results. The 1-cos gust response analysis of rigid (plunge and pitch) wing configuration is performed, and the lift response is calculated and compared with the six degree of freedom (6-DOF) equation results. The results indicate that at low Mach numbers the application of the grid speed method is an effective way to simulate gust responses. At high Mach numbers, however, nonlinear infection is a very important aspect in the simulation of gust response of wing configurations which should be considered in practical applications,while the coupling in 6-DOF equation does not seriously affect the calculated lift history.

Keywords: gust response strip theory finite volume method Euler equation six degree of freedom equation elastic wing modal superposition method

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