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用于变体翼梢小翼的伸缩栅格研究

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Research of Retractable Grid Applied to Morphing Winglet

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摘要 翼梢小翼能抑制翼尖涡流形成、降低机翼的诱导阻力,翼梢小翼的高度是对减阻效果影响较大的参数之一。传统翼梢小翼仅针对巡航状态设计,而在起降、爬升等非设计状态减阻效果不佳。变体翼梢小翼能根据飞行状态主动改变几何外形和尺寸,实时优化减阻效果。为了实现变形,设计了一种用于变体翼梢小翼的伸缩栅格,通过步进电机驱动,可使翼梢小翼的高度主动变化。采用机械系统动力学自动分析软件(ADAMS)研究了伸缩栅格的动力学特性。仿真结果表明:伸缩栅格在970.9 N·mm的电机转矩作用下,高度变化率可达13.9%,伸缩周期小于4.4 s;模型试验验证了该结果。以飞机起飞阶段的流场特性(马赫数Ma=0.1,迎角α=6°)为例,采用计算流体力学(CFD)与风洞试验相结合的方法,分析了变体翼梢小翼高度的变化对机翼翼尖尾涡流动结构和升阻特性的影响,结果表明:增大翼梢小翼的高度可显著降低翼尖涡强度,最大降幅约为47.7%;并可将机翼的升力系数提高3.5%,阻力系数降低4.8%。因此,采用伸缩栅格的变体翼梢小翼具有改善飞机起飞性能的潜力。

关键词: 变体翼梢小翼 伸缩栅格 小翼的高度 计算流体力学 风洞试验 增升 减阻

Abstract: Winglets can inhibit the formation of wingtip vortices and reduce the induced drag. The height of a winglet is one of the most critical parameters in drag reduction efficiency. Current winglet designs are typically optimized for cruise conditions. But they are inefficient in off-design conditions, such as takeoff, climb and landing. Morphing winglets can optimize the drag reduction efficiency through changing their geometric dimensions during flight. This paper investigates a retractable grid for morphing winglets which are actuated by a stepper motor to change the winglet heights at various flight conditions. According to the dynamic analysis based on automatic dynamic analysis of mechanical systems (ADAMS), the change rate of the winglet height reaches up to 13.9% and the cycle is less than 4.4 s when the motor torque is 970.9 N·mm. The simulation has been verified by model test. Subsequently, the effects of a morphing winglet on wingtip vortices and aerodynamic performance are estimated through computational fluid dynamics (CFD) and wind tunnel test. The test results show that increasing the winglet height is beneficial to inhibiting the wingtip vortices. The maximum decrease of wingtip vortices can be as high as 47.7%. With the increase of winglet height, the lift coefficient is also improved by 3.5% and the drag coefficient is reduced by 4.8% during the takeoff phase (Mach number Ma=0.1, angle of attack α=6°). Therefore, morphing winglet with retractable grid has the potential of improving aircraft takeoff performance.

Keywords: morphing winglet retractable grid the height of the winglet computational fluid dynamics wind tunnel test lift improvement drag reduction

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