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Flow-Control Effectiveness of Convergent Surface Indentations on an Aerofoil at Low Reynolds Numbers

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Abstract : Passive flow control on aerofoils has largely been achieved through the use of protrusions such as vane-type vortex generators. Consequently, innovative flow-control concepts should be explored in an effort to improve current component performance. Therefore, experimental research has been performed at The University of Manchester to evaluate the flow-control effectiveness of a vortex generator made in the form of a surface indentation. The surface indentation has a trapezoidal planform. A spanwise array of indentations has been applied in a convergent orientation around the maximum-thickness location of the upper surface of a NACA-0015 aerofoil. The aerofoil has been tested in a two-dimensional set-up in a low-speed wind tunnel at an angle of attack (AoA) of 3° and a chord-based Reynolds number (Re) of ~2.7 x 105. The baseline model has been found to suffer from a laminar separation bubble at low AoA. The application of the indentations at 3° AoA has considerably shortened the separation bubble. The indentations achieve this by shedding up-flow pairs of streamwise vortices. Despite the considerable reduction in bubble length, the increase in leading-edge suction due to the shorter bubble is limited by the removal of surface curvature and blockage (increase in surface pressure) caused locally by the convergent indentations. Furthermore, the up-flow region of the vortices, which locally weakens the pressure recovery around the trailing edge of the aerofoil by thickening the boundary layer, also contributes to this limitation. Due to the conflicting effects of the indentations, the changes in the pressure-lift and pressure-drag coefficients, i.e., cl,p and cd,p, are small. Nevertheless, the indentations have improved cl,p and cd,p beyond the uncertainty range, i.e., by ~1.30% and ~0.30%, respectively, at 3° AoA. The wake measurements show that turbulence intensity and Reynolds stresses have considerably increased in the indented case, thus implying that the indentations increase the viscous drag on the model. In summary, the convergent indentations are able to reduce the size of the laminar separation bubble, but conversely, they are not highly effective in reducing cd,p at the tested Reynolds number.

Keywords : aerofoil flow control, laminar separation bubbles, low Reynolds-number flows, surface indentations
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