Nonlinear Aeroelastic Behavior of Typical Section Model Near Ground

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This paper investigates the nonlinear aeroelastic behavior of a typical airfoil model in ground effect. Ground effect increases the lift and reduces the drag, which is helpful during the takeoff and landing of an aircraft. Ground effect has been equally explored in the design of ‘wing in ground’ craft. Despite the aerodynamic benefits of flying near the ground, it also causes flutter instability at a lower speed. The speed at which the instability occurs depends on the proximity of the aircraft from the ground. Similarly, the presence of freeplay nonlinearity in the control surface can exhibit a limit cycle oscillation (LCO) or chaotic vibration contributing to structural fatigue or response, leading to catastrophic failure. Therefore, in the presence of nonlinearity like freeplay, aeroelastic behavior in ground effect can potentially affect the aerodynamic performance.

In the present study, the aeroelastic model consists of a typical airfoil section with a trailing edge flap, elastically supported by flexural and torsional springs. The aerodynamic force is computed using the two-dimensional unsteady vortex lattice method (2D-UVLM) and mirror-image method to simulate the flow near the ground. The freeplay nonlinearity is introduced in the pitch, and flap motions. The numerical solution involves an iterative scheme based on the predictor-corrector method. LCOs and chaotic vibration are observed below the linear flutter boundary due to the freeplay in a flap as shown in Fig. 1. Similarly, near ground with freeplay, a decrease in the vibration amplitude can decrease the effective angle of attack, and affect the aerodynamic performance. Thus, the presence of freeplay nonlinearity near the ground can be a real concern.

Table 1 Model parameters

<table>
<thead>
<tr>
<th>$a$</th>
<th>$e$</th>
<th>$X_{a0}$</th>
<th>$X_{l0}$</th>
<th>$r_{a0}$</th>
<th>$r_{l0}$</th>
<th>$\omega_{a0}/\omega_{n}$</th>
<th>$\omega_{l0}/\omega_{n}$</th>
<th>$\mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.4</td>
<td>0.6</td>
<td>0.2</td>
<td>0.0125</td>
<td>0.25</td>
<td>0.00625</td>
<td>0.5</td>
<td>0.1667</td>
<td>40</td>
</tr>
</tbody>
</table>

Fig. 1 Time histories of chaotic vibration and LCOs of the flap

Fig. 2 LCOs far from ground and near ground ($d = 0.5c$)

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