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Aerodynamic Modeling of an Unmanned Aerial Vehicle using Vortex Lattice Method

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The determination of a aircraft aerodynamic characteristics is an important stage in aircraft flight simulation. In order to compose the flight aircraft equations of motions the computation of the aerodynamics stability and control derivatives is needed. In this work will presented a methodology to modeling the aerodynamic and flight dynamics characteristics of an Unmanned Aerial Vehicle (UAV). The steady aerodynamic coefficients are calculated based on the vortex-laticce method. The research platform is the Vector-P UAV [1, 2] shown in the Fig. 1.

Figure 1: Vector-P UAV.

The six-degree of freedom of aircraft motion are described as [3]:

$$\begin{aligned}
\dot{u} - rv + qw + g\sin\theta &= \frac{X}{m} \\
\dot{v} - pw + ru - g\sin\phi\cos\theta &= \frac{Y}{m} \\
\dot{w} - qu + pv - g\cos\phi\cos\theta &= \frac{Z}{m} \\
I_{xx}\dot{p} - (I_{xy}\dot{p} + I_{yz}\dot{r}) + (I_{zz} - I_{yy})qr + (I_{xy}r - (I_{xz}q)p + (r^2 - q^2)I_{yz} &= \mathcal{L} \\
I_{yy}\dot{q} - (I_{xy}\dot{q} + I_{xz}\dot{r}) + (I_{xx} - I_{zz})pr + (I_{yz}p - (I_{xz}r)q + (p^2 - r^2)I_{xz} &= \mathcal{M} \\
I_{zz}\dot{r} - (I_{xz}\dot{p} + I_{yz}\dot{q}) + (I_{yy} - I_{xx})pq + (I_{xz}q - (I_{yz}p)r + (q^2 - p^2)I_{xy} &= \mathcal{N}
\end{aligned} \tag{1}$$

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For the calculation of the aerodynamic properties, AVL software was used. AVL software uses the Vortex Lattex (Vortex Lattex Method-VLM) method, which is a panel theory method based on potential flow [4]. Corrections are made to account for viscosity effects.

The aerodynamic forces and moments coefficients are assumed to be composed of the linear superposition of loads in the rigid body motion variables (dynamic states and control surfaces):

$$C_L = C_{L_0} + C_{L_\alpha}\alpha + C_{L_q}\frac{qc}{2V} + C_{L_{i_h}} i_h \tag{2}$$

$$C_D = C_{D_0} + \frac{1}{\pi A e} C_L^2 \tag{3}$$

$$C_Y = C_{Y_\beta}\beta + C_{Y_p}\frac{pb}{2V} + C_{Y_r}\frac{rb}{2V} + C_{Y_{\delta_a}}\delta_a + C_{Y_{\delta_r}}\delta_r \tag{4}$$

$$C_M = C_{M_0} + C_{M_\alpha}\alpha + C_{M_q}\frac{qc}{2V} + C_{M_{i_h}} i_h \tag{5}$$

$$C_N = C_{N_\beta}\beta + C_{N_p}\frac{pb}{2V} + C_{N_r}\frac{rb}{2V} + C_{N_{\delta_a}}\delta_a + C_{N_{\delta_r}}\delta_r \tag{6}$$

$$C_l = C_{l_\beta}\beta + C_{l_p}\frac{pb}{2V} + C_{l_r}\frac{rb}{2V} + C_{l_{\delta_a}}\delta_a + C_{l_{\delta_r}}\delta_r \tag{7}$$

To model the Vector-P using VLM, each part, like the wing, tail and fuselage needs to be model separately and all have different setting. Initially the geometric properties of the aircraft will be introduced and the layout of geometric partitions will be defined. Subsequently, the VLM allows the creation of an aerodynamic influence matrix that relates the different sub-parts of the aircraft. The longitudinal and lateral aerodynamic derivatives will be obtained for cruise flight condition.

Based on calculated aerodynamic aircraft derivatives can be created an environment to simulate the dynamics of the aircraft.The aerodynamic derivatives (stability) calculated by VLM can be used as a starting point and later compared and validated with the corresponding aerodynamic derivatives identified from experimental flight data.

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