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Flight characteristic analysis of Solar UAV by MATLAB/SIMULINK

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-Background-
Recently, necessity of airplane that can perform observation for long time flight is increasing. However, a conventional manned airplane with fuel cannot carry out flight mission for long period such as weeks or months. Since the Solar UAV can be supplied energy by using the solar cell, an automatic long period flight is possible.
Solar UAV named Sun Falcon 1(Fig.1) is designed for flight over 10 hours by only solar energy. And Sun Falcon 2 will be designed for flight during 5 days only solar energy by autonomous flght. To get the optimum tail condition and develop the control law, we have to analyze the stability and controllability at the first step.

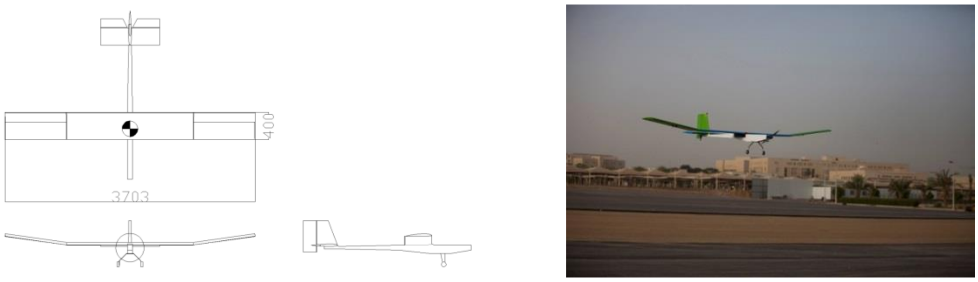

Fig.1 Sun Falcon 1

Sun Falcon 1 has been finished successfully. But it doesn’t has the control law and ECU therefore it had been controled by pilot.
Despite we don’t have the experience how to develop the control law, we have to develop it until march 2014. Although we the design of Sun Falcon 2 hasn’t finished, we have to make it until march 2015. Therefore we are using the Hardware In the Loop Simuration (HILS) in order to cut the term of development and prevent the accident.

-Objective-
To develop the optimum control law and Sun Falcon 2, we analyse the Sun Falcon 1 about controllability and stability, and estimate for the tail condition of Sun Falcon 2.

-Specification-
The designed Solar UAV named Sun Falcon 1 has the following specification; b is 3.7[m], AR is 9.2 with rectangle wing, total mass is 7.1[kg]. Solar UAV was manufactured and the radio control test flight was carried out at KAU in Saudi Arabia. We can understand that the designed solar UAV can fly by solar energy with battery assisted for day flight.
Table.1(b) shows dimensional derivatives. These were determined from the linearized disturbance equation.

Table.1 Dimensional derivatives

X_u (s^{-1})	-0.078	$M_{\dot{\alpha}}$ (s^{-1})	-2.447
Z_u (s^{-1})	-1.412	Z_q (m s^{-1})	-1.425
M_u (m^{-1} s^{-1})	0	M_q (s^{-1})	-6.780
X_α (m s^{-2})	5.301	Z_{δ_e} (m s^{-2})	-7.916
Z_α (m s^{-2})	-112.599	M_{δ_e} (s^{-2})	-37.670
M_α (s^{-2})	-22.531		

-Analysis condition-

Equation of motion is expressed Eq. (1) and (2). Eq.(1) is longitudinal equation. Eq.(2) means lateral equation. Fig.2 shows that Eq.(1) and (2) heve been expressed by SIMULINK. In this case, analysis is finished only longitudinal condition. Lateral condition and Sun Falcon 2 have been progressing.

$$\begin{aligned}
&(D - X_u)u - X_\alpha \alpha + g\theta = 0 \\
&-Z_u u + (U_0 D - Z_\alpha)\alpha - (U_0 + Z_q)D\theta = Z_{\delta e}\delta e \\
&-M_u u - (M_{\dot{\alpha}} D + M_\alpha)\alpha + (D - M_q)D\theta = M_{\delta e}\delta e \\
&D\theta = q
\end{aligned} \quad (1)$$

$$\begin{aligned}
&(U_0 D - Y_\beta)\beta - (Y_p D + g)\phi + (U_0 - Y_r)r = Y_{\delta r}\delta_r \\
&-L'_\beta \beta + (D - L'_p)D\phi - L'_r r = L'_{\delta a}\delta_a + L'_{\delta r}\delta_r \\
&-N'_\beta \beta - N'_p D\phi + (D - N'_r)r = N'_{\delta a}\delta_a + N'_{\delta r}\delta_r
\end{aligned} \quad (2)$$

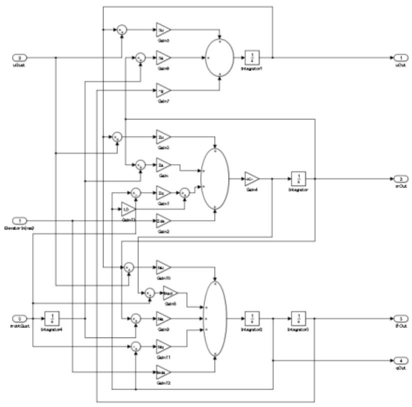

Fig.2 Equation of motion on SIMULINK.

-Results-

Fig.3 shows that Sun Falcon 1 has longitudinal static stability and dynamic stability. We think that short period and Phugoid damping ratio should be 0.707($1/\sqrt{2}$) each other. Phugoid mode damping ratio is worse but it can be fixed by control. But tail condition should be changed before being fixed by control (Fig.4). Because if the ECU get the accident, the plane has to fly as long as possible, in order to be repaired or recovered the control.

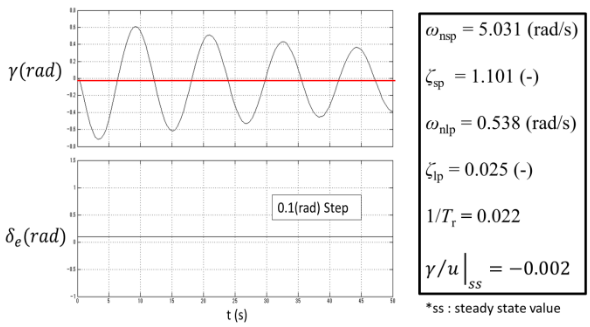

Fig.3 response of elevator(0.1 rad).

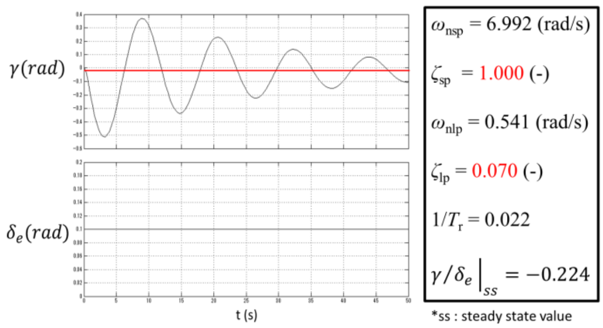

Fig.4 result of fixed tail location.

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