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Incidence Variation of a Tumbling Wing

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Preamble

The analysis concerns the motion of a tumbling wing configured to be a suspended trike microlight aircraft

Nomenclature

Variable	Description
U	Forward Speed
s	Distance along Wing – Origin at Suspension Point
Ω	Tumble Rotational Speed
ψ	Azimuth Angle of Microlight
θ	Pitch Angle of Wing Relative to Trike
ϕ	Angle Centred at Trike Base subtended between Trike and Lin to Control Point
δ	Angle of Rotational Velocity Relative to Wing
β	Inclination of Point Velocity Relative to Wing Surface

Method

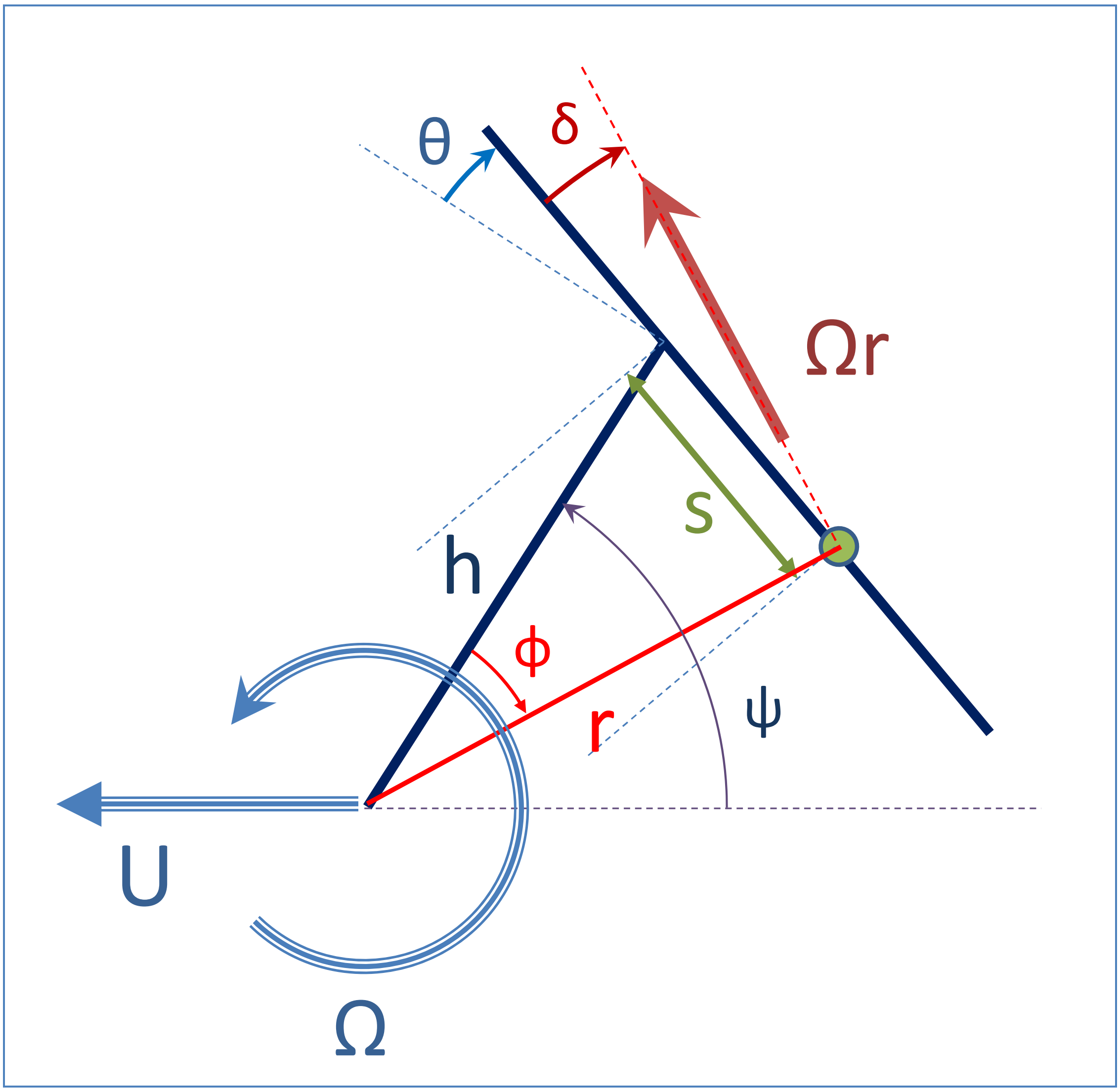

Figure 1

Using the Cosine Rule we have:

$$r = \sqrt{h^2 + s^2 - 2hs\cos\left(\frac{\pi}{2} - \theta\right)} \qquad (1.)$$
$$= \sqrt{h^2 + s^2 - 2hs\sin\theta}$$

Using the Sine Rule:

$$u_r = \Omega r \cdot \cos\delta$$
$$v_r = \Omega r \cdot \sin\delta \qquad (4.)$$

$$\frac{s}{\sin\phi} = \frac{r}{\sin\left(\frac{\pi}{2} - \theta\right)} = \frac{r}{\cos\theta} \qquad (2.)$$
$$\sin\phi = \frac{s}{r}\cos\theta$$

The rotational velocity of the wing in directions parallel and perpendicular to the wing is:

Via the geometry in Figure 1, we have the following:

$$\delta = \phi - \theta \qquad (3.)$$

whence:

The translational velocity of the wing in directions parallel and perpendicular to the wing is:

Using the following definitions:

$$
\begin{aligned}
u_{TOT} &= \Omega r \cdot \cos(\phi - \theta) + U \sin(\psi - \theta) \\
&= V_T \left\{ \frac{r}{h} \cos(\phi - \theta) + \mu \sin(\psi - \theta) \right\} \\
v_{TOT} &= \Omega r \cdot \sin(\phi - \theta) - U \cos(\psi - \theta) \\
&= V_T \left\{ \frac{r}{h} \sin(\phi - \theta) - \mu \cos(\psi - \theta) \right\}
\end{aligned}
\qquad (8.)
$$

$$
\begin{aligned}
V_T &= \Omega h \\
\mu &= \frac{U}{V_T}
\end{aligned}
\qquad (7.)
$$

$$
\begin{aligned}
u_r &= \Omega r \cdot \cos(\phi - \theta) \\
v_r &= \Omega r \cdot \sin(\phi - \theta)
\end{aligned}
\qquad (5.)
$$

The total velocity components parallel and perpendicular to the wing are given by:

$$
\begin{aligned}
u_t &= U \sin(\psi - \theta) \\
v_t &= -U \cos(\psi - \theta)
\end{aligned}
\qquad (6.)
$$

From which the total speed is given by:

And the inclination to the wing:

$$\tan\beta = \frac{v_{TOT}}{u_{TOT}} = \frac{\frac{r}{h}\sin(\phi-\theta)-\mu\cos(\psi-\theta)}{\frac{r}{h}\cos(\phi-\theta)+\mu\sin(\psi-\theta)} \quad (10.)$$

$$\begin{aligned} q &= \sqrt{u_{TOT}^2 + v_{TOT}^2} \\ &= V_T\left\{\left(\frac{r}{h}\right)^2 + \mu^2 + 2\sin\left[(\psi-\theta)-(\phi-\theta)\right]\right\} \\ &= V_T\left\{\left(\frac{r}{h}\right)^2 + \mu^2 + 2\sin(\psi-\phi)\right\} \end{aligned} \quad (9.)$$