

Aerodynamics & Flight Mechanics Research Group

Incidence Variation of a Tumbling Wing

S. J. Newman

Technical Report AFM-11/16

January 2011

UNIVERSITY OF SOUTHAMPTON

SCHOOL OF ENGINEERING SCIENCES

AERODYNAMICS AND FLIGHT MECHANICS RESEARCH GROUP

Incidence Variation of a Tumbling Wing

by

S. J. Newman

AFM Report No. AFM 11/16

January 2011

© School of Engineering Sciences, Aerodynamics and Flight Mechanics Research Group



COPYRIGHT NOTICE

(c) SES University of Southampton All rights reserved.

SES authorises you to view and download this document for your personal, non-commercial use. This authorization is not a transfer of title in the document and copies of the document and is subject to the following restrictions: 1) you must retain, on all copies of the document downloaded, all copyright and other proprietary notices contained in the Materials; 2) you may not modify the document in any way or reproduce or publicly display, perform, or distribute or otherwise use it for any public or commercial purpose; and 3) you must not transfer the document to any other person unless you give them notice of, and they agree to accept, the obligations arising under these terms and conditions of use. This document, is protected by worldwide copyright laws and treaty provisions.



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

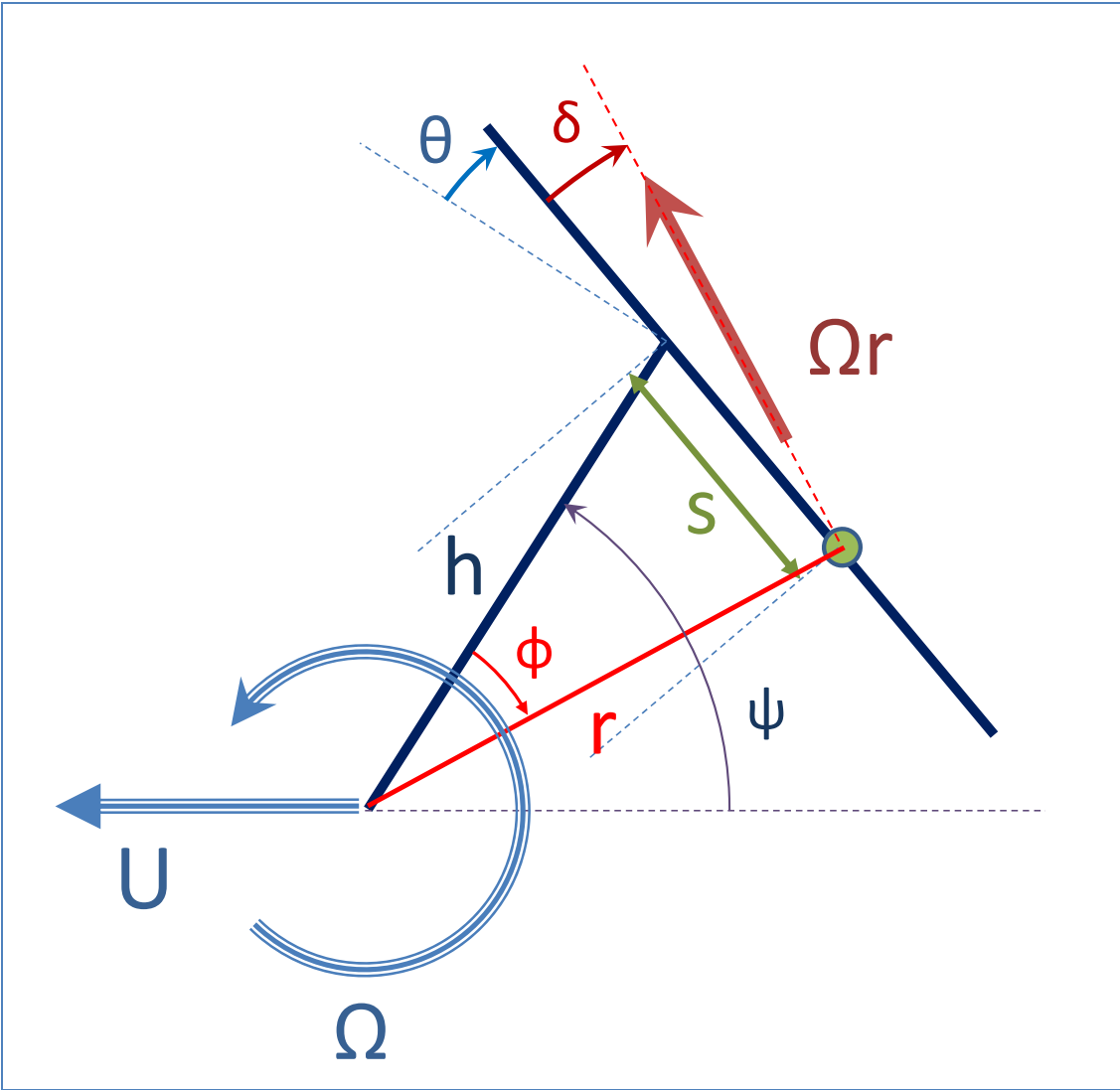


Figure 1

Using the Cosine Rule we have:



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

Using the Sine Rule:

$$\begin{aligned}
 u_r &= \Omega r \cdot \cos \delta \\
 v_r &= \Omega r \cdot \sin \delta
 \end{aligned}
 \tag{4.}$$

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

$$\sin \phi = \frac{s}{r} \cos \theta$$

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:

$$\delta = \phi - \theta
 \tag{3.}$$

whence:



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

Using the following definitions:

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

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

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

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

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

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



From which the total speed is given by:

And the inclination to the wing:

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

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

