UNIVERSITY OF
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Aerodynamics & Flight Mechanics Research Group

Modelling Ground Effect (Cheesman & Bennett + Leishman)

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Technical Report AFM-11/17

January 2011

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Introduction

The following analysis is referenced in Cheeseman & Bennet together with Leishman.

Analysis

Hover

Chesseman & Bennet model the rotor in gorund effect by using a source term as the image. This gives the following formula:

$$\frac{T_{IGE}}{T_{OGE}} = \frac{1}{1-\left(\frac{R}{4Z}\right)^2} = \frac{1}{1-\left(\frac{1}{4\overline{Z}}\right)^2} \qquad \textbf{(1.)}$$

$$\overline{Z} = \frac{Z}{R}$$

This has a limitation on the minimum value of height ratio:

$$\overline{Z} > 0.25 \qquad \textbf{(2.)}$$

Forward Flight

This formula has been extended into forward flight by Leishman thus:

$$\frac{T_{IGE}}{T_{OGE}} = \frac{1}{1 - \frac{\left(\frac{R}{4Z}\right)^2}{1 + \left(\frac{\mu}{\lambda_i}\right)^2}} = \frac{1}{1 - \left(\frac{\cos\chi}{4\bar{Z}}\right)^2} \qquad (3.)$$

$$\tan\chi = \frac{\mu}{\lambda_i}$$

Here the wake angle (χ) has been introduced.

If the rotor disc is assumed to be parallel to the forward flight direction, weh vae the following result from momentum theory:

$$\lambda_i = \frac{C_T}{4} \cdot \frac{1}{\sqrt{\mu^2 + \lambda_i^2}} \qquad (4.)$$

Equation 4 can be recast by clearing the fractions, thus:

$$\lambda_i^2\left(\mu^2 + \lambda_i^2\right) = \left(\frac{C_T}{4}\right)^2$$

$$\left(\lambda_i^2\right)^2 + \mu^2\left(\lambda_i^2\right) - \left(\frac{C_T}{4}\right)^2 = 0 \qquad (5.)$$

On substituting the expression for the wake angle this becomes:

$$\left(\mu^2 \cot^2 \chi\right)^2 + \mu^2\left(\mu^2 \cot^2 \chi\right) - \left(\frac{C_T}{4}\right)^2 = 0 \qquad \textbf{(6.)}$$

Which, after manipulation gives:

$$\cos \chi = \frac{2}{C_T} \cdot \left\{ \sqrt{\mu^4 + \frac{C_T^2}{4}} - \mu^2 \right\} \qquad \textbf{(7.)}$$