Tail Attachment Documentation

Date Started: October 10th, 2023

Role	Name	Email
Project Member	*Nicholas Chu*	*nchu2405@gmail.com*
Project Member	*Justin Yoon*	*jyoon1325@gmail.com*

Table of Contents

Project Overview

This project revolves around determining an appropriate tail arm, as well as sizing the vertical and horizontal tails. This was completed in a spreadsheet, which made use of the formulae given in Chapter 11 of Snorri Gudmundsson's "General Aviation Aircraft Design". This spreadsheet was made adaptive to account for changes in design that would alter key parameters necessary for sizing the tail.

Key differences between this year's tail sizing project and those conducted previously are the adaptation of necessary formulae to apply to an inverted U-tail.

Modifying Equations

The equations taken from Snorri Gudmundsson's textbook could largely be used without modification. The major alterations come as a result of our tail boom geometry. This year's plane's configuration is a twin boom inverted U-tail. This creates significant complications, as we have twice the wetted surface area on the vertical stabilizers, as well as on the booms themselves. Furthermore, we chose a unique geometry for our booms, opting for two flat vertical panels. This further alters the wetted surface area.

The equation that needed to be modified. This is because it is optimized to minimize the total wetted area. Full derivations for the modifications are shown below.

EXAMPLE 11-4

A small airplane is being designed with a twin tail boom configuration (see Figure 11-44). Derive an expression similar to Equation (11-28) for the drag optimized tail arm. Use R_1 and R_2 to represent the base and top radii of each boom and assume S_{VT} to represent to total VT area.

SOLUTION:

Following the same procedure, we define the total wetted area as follows. Note that we have *two* tail booms and not one as before. Therefore, note the slight change to Equation (11-14):

$$S_{wet} = 2 \cdot \pi (R_1 + R_2) \cdot l_T + 2\frac{V_{HT} \cdot S \cdot c_{MGC}}{l_T} + 2\frac{V_{VT} \cdot S \cdot b}{l_T} \quad \text{(i)}$$

Differentiate Equation (i) with respect to l_T:

$$\frac{dS_{wet}}{dl_T} = \frac{d}{dl_T}\left(2\pi(R_1 + R_2) \cdot l_T + 2\frac{V_{HT} \cdot S \cdot c_{MGC}}{l_T} + 2\frac{V_{VT} \cdot S \cdot b}{l_T}\right)$$

$$= 2\pi(R_1 + R_2) - \frac{2 \cdot S}{l_T^2}(V_{HT} \cdot c_{MGC} + V_{VT} \cdot b)$$

Set to zero to determine the optimum tail arm:

$$\frac{dS_{wet}}{dl_T} = 0 \quad \Rightarrow \quad l_T^2 = \frac{S(V_{HT} \cdot c_{MGC} + V_{VT} \cdot b)}{\pi(R_1 + R_2)}$$

$$\Rightarrow \quad l_T = \sqrt{\frac{S(V_{HT} \cdot c_{MGC} + V_{VT} \cdot b)}{\pi(R_1 + R_2)}}$$

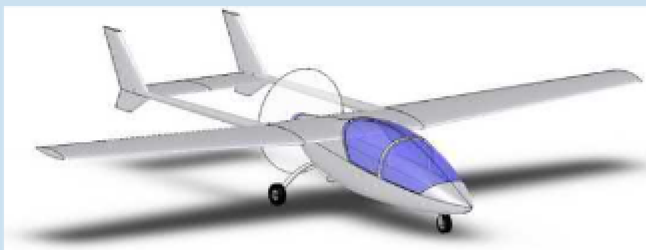

FIGURE 11-44 A small twin tail boom configuration.

Tail Arm Length Derivation

The total wetted surface area can be expressed as:

$$S_{wet} = 4 \cdot \left(\frac{T_1 + T_2}{2}\right) \cdot L_T + 2 \cdot \left(\frac{V_{HT} \cdot S_{REF} \cdot c_{REF}}{L_T}\right) + 2 \cdot \left(\frac{V_{VT} \cdot S_{REF} \cdot b_{REF}}{L_T}\right),$$

Differentiating and setting equal to zero to minimize wetted area yields:

$$\frac{dS_{wet}}{dL_T} = 2(T_1 + T_2) - 2\frac{V_{HT} \cdot S_{REF} \cdot c_{REF} + V_{VT} \cdot S_{REF} \cdot b_{REF}}{{L_T}^2} = 0,$$

$$L_T = \sqrt{\frac{S_{REF}(V_{HT} \cdot c_{REF} + V_{VT} \cdot b_{REF})}{T_1 + T_2}}$$

Determining the Volume Coefficients

Because our aircraft has a unique configuration, not many mass-produced aircraft exist today that have the same layout. As such, we were unable to take the volume coefficients from Snorri Gudmundsson's textbook. Instead, we opted to search online, deciding that a modern UAV is the closest comparison to our aircraft due to its relatively slow speed and small size. Through this research, we were able to find suitable volume coefficients, which are displayed below.

Empennage General Design	
Vertical tail volume coefficient (V_v)	0.04
Horizontal tail volume coefficient (V_h)	0.6

Nugroho, G., Zuliardiansyah, G., & Rasyiddin, A. A. (2022, April 11). *Performance analysis of empennage configurations on a surveillance and monitoring mission of a VTOL-plane UAV using a computational fluid dynamics simulation*. MDPI. https://www.mdpi.com/2226-4310/9/4/208