The Pennsylvania State University

The Graduate School

# **Wake Modeling of UH-60 Black Hawk**

**Project 1**

By Zarif Rahman

Submitted by

Zarif Rahman

AERSP 597

Rotorcraft Aerodynamics and Acoustics

Master of Science

March 2022

Table of Contents

[**Wake Modelling of UH-60 Black Hawk** 1](#_Toc99306318)

[Objective: 3](#_Toc99306320)

# Objective:

The focus of the first project was to evaluate the required power and thrust based on a uniform inflow, but for this project, it is meant to be an extension with the implementation of the wake of the UH-60 helicopter. The objective was to primarily find the tip vortex and use that information to iterate for the calculation of induced velocity, which in turn gives the thrust.

# Technical Approach:

The previous blade element code was to begin creating a wake geometry code with the incorporation of Biot-Savart to output the induced velocity. The primary goal here was to get the thrust and power with the addition of the wake. The approach for finding this induced velocity was to find the constant circulation using the thrust BET output for the previous calculation. This then was used throughout the code for an initial guess of the circulation. This then was iterated throughout the rest of the code to find convergence. To do this another objective was to find a wake geometry which was done using Beddoes prescribed wake model with using a wake age and

The assumptions and information carried over from the last project with them being the following:

Specifications (Shinoda, Yeo, Norman):

* Airfoils: SC1095 & SC1094R8
* Blades: 4
* Radius: 26.83 [ft]
* Angular velocity: 258 [rpm]
* Rotor Disk Area: 2261.5 [ft2]
* Blade Area: 186.9 [ft2]
* Root Cut out = 4.5611 [ft]
* f = 32.95 ft^2 to 36.34 ft^2 Chord, from 20.76/20.965 in using 20.76 ignoring taper

Assumptions for now:

* Clα = 2𝛑
* Cd0 = 0.01
* V∞ = 174 mph
* αTPP = -2
* Constant chord with no twist distribution

# Results:

# Conclusion:

The data from the code explicitly shows the impact that the wake has on performance. Using the Beddoes model for the wake the code identified that the performance curves are shifted with their requiring slightly more power opposed to Mangler and Squire. The Beddoes gave us a wake geometry that was similar to prediction as it had a tip vortex that was non-uniform and completely harmonic like a rigid wake. In non-uniform inflow and uniform inflow, the power was also different than the wake model in having 41.045 and 42.059\*10^4 kW power whereas the wake model predicted \_\_\_\_\_\_\_\_\_\_\_\_ of power. At the same time, the thrust which was also expected to be hindered by the wake was seen in the code.

# References:

1. Beddoes, T.S. “A Wake Model for High Resolution Airloads.” 2nd International Conference on Basic Rotorcraft Research, 1985.
2. Leishman, J. Gordon. *Principles of Helicopter Aerodynamics*. Cambridge University Press, 2017.
3. Shinoda, Patrick M., et al. “Rotor Performance of a UH‐60 Rotor System in the NASA Ames 80‐ by 120‐Foot Wind Tunnel.” *Latest TOC RSS*, Vertical Flight Society, 1 Oct. 2004, https://www.ingentaconnect.com/content/ahs/jahs/2004/00000049/00000004/art00003.
4. Totah, Joseph. *A Critical Assessment of UH-60 Main Rotor Blade Airfoil Data - NASA*. https://ntrs.nasa.gov/api/citations/19940027557/downloads/19940027557.pdf.