REPORT

PROJECT - PREFINAL STUDY
Programming Assignment II
Performance Calculations
HOVER CASE

Helicopter Theory

Uck459E - 22532

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- Introduction

In the first assignment, the AH-1W Cobra helicopter was selected and information was given about this helicopter. In line with this information, the required input values for the matlab code were taken as discussed below. The required power and power coefficient of the main rotor of the helicopter, the thrust force developed by the tail rotor, the required power and power coefficient of the tail rotor, excess power, merit and rate of climb shall be calculated for different altitude values.
Operating density altitudes as $h_{\varrho} = 1\ km,\ 3\ km\ and\ 5\ km$

Contractor	Bell Helicopter, Textron, Inc. (Prime), General Electric, Kollsman Inc.
Power Plant	Two General Electric T700-GE-401 Turboshaft engines (1,690 horsepower each)
Main rotor diameter	14.63 m
Main rotor blade chord	0.84 m
Tail rotor diameter	2.97 m
Tail rotor blade chord	0.305 m
Distance between rotor centers	8.89 m
Wing span	3.28 m
Wing aspect ratio	3.74
Length (overall, rotors turning)	17.68 m
Length (fuselage)	13.87 m
Width overall	3.28 m
Height (to top of rotor head)	4.11 m
Overall height	4.44 m
Ground clearance (main rotor, turning)	2.74 m
Elevator span	2.11 m
Width over skids	2.24 m

Weight empty	4,634 kg
Mission fuel load (usable)	946 kg
Maximum useful load (fuel and disposable ordinance)	2,065 kg
Maximum Takeoff and landing weight	6,690 kg
Maximum disc loading	39.80 kg/m^2
Maximum power loading	4.42 kg/kW
Main rotor blades (each)	6.13 m^2
Tail rotor blades (each)	0.45 m^2
Main rotor disc	168.11 m^2
Tail rotor disc	6.94 m^2
Vertical fin	2.01 m^2
Horizontal tail surfaces	1.41 m^2
Climb rate	1,925 feet
Maximum altitude	14,750 feet
Maximum attainable speed	170 knots
Maximum cruising speed	152 knots

AH1W - COBRA

- 1) Equation Theory

- a) First, the air temperature at different altitudes and the pressure accordingly were calculated. As a result, density ratios were calculated for these heights. Troposphere equations in Figure 1.1 are used.

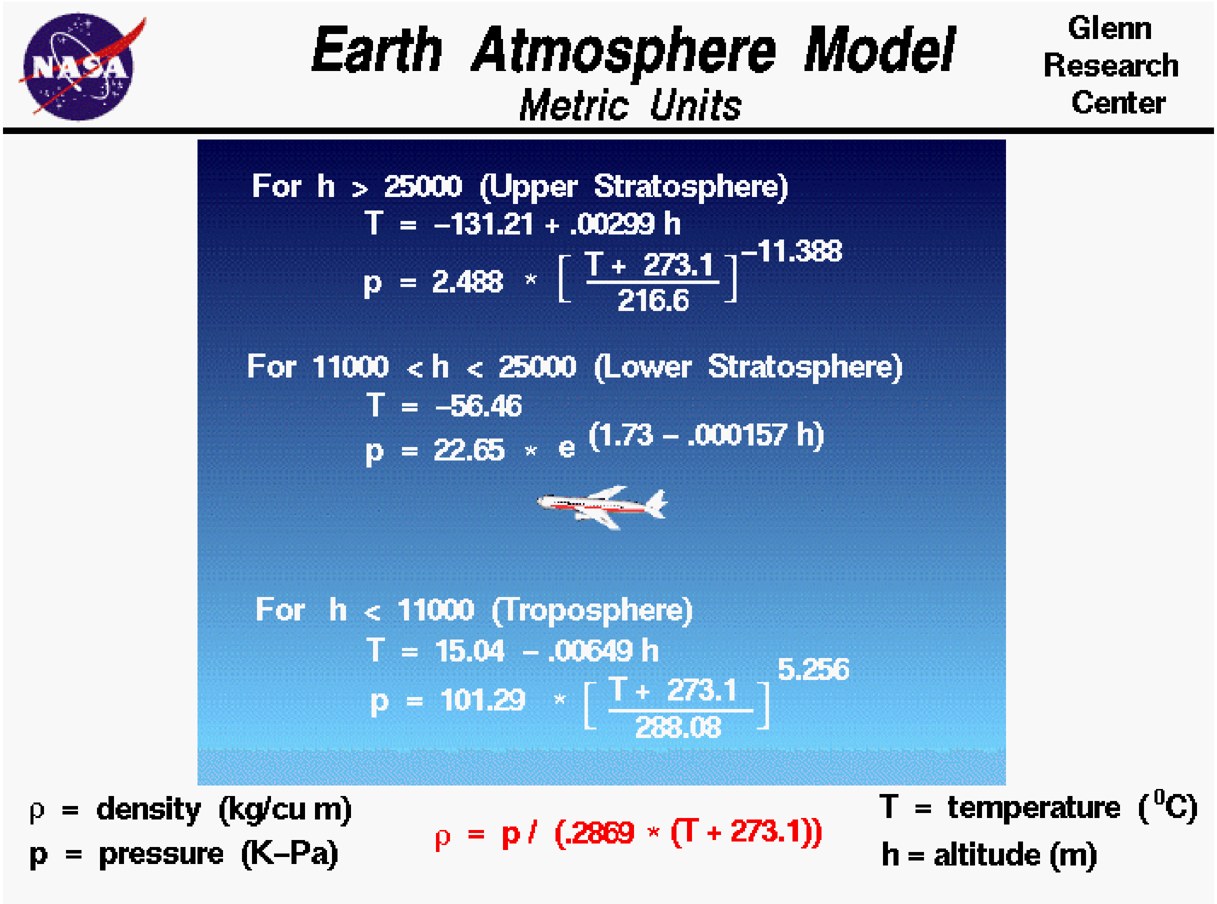

Figure 1.1

- b) The AH1W- Cobra has two General Electric T700-GE-401 engines, both have 1300kW power, for variable altitude using the equation below.

$$P = P_0 \frac{\rho}{\rho_0}$$

- c) The required power and power coefficient of the main rotor were calculated using the following equations.

$$(P_{main})_h = P_i + P_0 = \frac{\kappa T^{3/2}}{\sqrt{2\rho A}} + \rho A(\Omega R)^3 \frac{\sigma C_{d0}}{8}$$

$$C_p = \frac{P_i + P_0}{\rho \times A \times (\Omega \times R)^3}$$

- d) To calculate the thrust produced by the tail rotor, the distance between the main rotor and the tail rotor and the main engine torque were needed.

$$(Q_{main})_h = (P_{main})_h / \Omega \,)$$

$$T_{tail} = \frac{Q_{main}}{Dstncem\_t}$$

- e) The following equations were used to calculate the required power and power coefficient of the tail rotor.

$$(P_{tail})_h = P_{i_{tr}} + P_{0tr} = \left(\frac{\kappa T^{3/2}}{\sqrt{2\rho A}}\right)_{tr} + \left[\rho A(\Omega R)^3 \frac{\sigma C_{d0}}{8}\right]_{tr}$$

$$(C_p)_{tail} = \frac{(P_i)_{tail} + (P_0)_{tail}}{\rho \times A_t \times (\Omega_t \times R_t)^3}$$

- f) Following equations were used to calculation of the excess power at each altitude

$$\Delta P = P_{available} - [(P_{main})_h + (P_{tail})_h]$$

- g) The Figure of Merit (FM) equation, which measures the aerodynamic performance of a rotor while suspended in air at variable altitude, is as follows.

$$C_t = \frac{T}{\rho \times (\Omega \times R)^2 \times A}$$

$$P_{ideal} = \frac{C_t^{3/2}}{\sqrt{2}}$$

$$P_h = k \times P_{ideal} + \frac{\sigma C_{d0}}{8}$$

$$FM = \frac{P_{ideal}}{P_h}$$

- ## 2) Table

Altitude (km)	1 km	3 km	5 km
Air density (kg/m^3)	1.1141	0.9115	0.7383
Available power (W)	2.3646 1.0e+06 *	1.9345 1.0e+06 *	1.5670 1.0e+06 *
Required induced power (main rotor) (W)	6.3640 1.0e+05 *	7.0360 1.0e+05 *	7.8177 1.0e+05 *
Required profile power (main rotor) (W)	2.8597 1.0e+05 *	2.3395 1.0e+05 *	1.8950 1.0e+05 *
Required induced power (tail rotor) (W)	4.2223 1.0e+04 *	4.7838 1.0e+04 *	5.6047 1.0e+04 *
Required profile power (tail rotor) (W)	6.5698 1.0e+03 *	5.3747 1.0e+03 *	4.3536 1.0e+03 *
Excess power (m/s)	1.3935 1.0e+06 *	0.9438 1.0e+06 *	0.5353 1.0e+06 *
Figure of Merit	0.6000	0.6526	0.6999

- ## 3) Comments

  - As the altitude rises above sea level, the air density decreases as the temperature and pressure decrease. The AH1W-Cobra has a turboshaft engine. These engines are a type of gas turbine engine designed to generate shaft power instead of jet thrust, that is, to generate power by pushing air. As the density of this air decreases, the total thrust also decreases. As the helicopter weight remains the same, the higher the helicopter is, the more power is used to keep the helicopter in the air. As the density decreases, the thrust produced by the main rotor decreases. When the density decreases, the required profile force decreases as the rotor system can move more easily due to the density. Therefore, as the height of the helicopter increases, the required profile power decreases. The explanations for the tail rotor are the same, the higher the helicopter's height, the higher the overall power consumption. As the altitude increases, the total power produced by the motor decreases and the total power consumption increases.

- Codes

```
clc
clear all
Ro = 1.225;                     % Sea level air density at  - kg/m^3
To = 288.15;                    % Sea level air temparature - K
altitude = [1000,3000,5000];    % Given density altitudes - m
k = 1.15;                       % In hover case k value is 1.10-1.15
Gtow = 4953*9.81;               % Weight of helicopter - N
T = Gtow;                       % Thrust in hover case - N
% Main Rotor
Po = 2*1300*1000;               % 2× General Electric T700 engine - W
N = 2;                          % Number of blades
r = 14.6/2 ;                    % Rotor radius (Rotor diameter 14.6m) - m
Da = 168.11;                    % Disc area - m^2
omega = 2*pi*(360/60);          % Velocity, RPM = 360 - 1/s
Cdo = 0.008;                    % Drag coefficient
c = 0.84;                       % Chord - m
solidity = N*c/(pi*r);          % Solidity
% Tail Rotor
Nt = 2;                         % Number of blades
rt = 2.97/2 ;                   % Rotor radius (Rotor diameter 2.97m) - m
Dat = 6.94;                     % Disc area - m^2
omega_t = 2*pi*(1200/60);       % Velocity, RPM = 1200 - 1/s
Cdot = 0.008;                   % Drag coefficient
ct = 0.305;                     % Chord - m
solidityt = Nt*ct/(pi*rt);      % Solidity
Dstncem_t = 8.89;               % Distance between rotor centers - m
% a) Calculation of the air density at 3 different altitudes, ρ
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Talt = 15.04 - 0.00649 * altitude

Pres = (101.29) * ((Talt + 273.15)/288.08).^(5.256)

Roalt =  Pres./(0.2869*(Talt + 273.15))

% b) Calculation of the available engine power at different altitudes.

Poav = Po.*(Roalt/Ro)

% c) Power and power coefficient of the main rotor at each altitude

Pim = (k.*T.^1.5)./(sqrt(2.*Roalt*Da))

Pom = Da.*Roalt.*((omega*r)^3)*solidity*Cdo/8

Phm = Pim + Pom

Cpm = Phm./(Roalt.*Da.*((omega*r)^3))

% d) Calculation of the thrust developed by the tail rotor

Q_main_h = Phm./omega

T_t = Q_main_h./Dstncem_t

% e) Power and power coefficient of the tail rotor at each altitude

Pit = (k.*T_t.^1.5)./(sqrt(2.*Roalt*Dat))

Pot = Dat.*Roalt.*((omega_t*rt)^3)*solidityt*Cdot/8

Pht = Pit + Pot

Cpt = Pht./(Roalt.*Dat.*((omega_t*rt)^3))

% f) Calculation of the excess power at each altitude

Deltap = Poav - (Phm+Pht)

% Calculation of available maximum climb velocity

V_c = Deltap./Gtow

% g) Calculation of the Figure of Merit (FM) at each altitude

ct =T./(Roalt.*(omega.*r).^2.*Da)

Pideal = ct.^(3/2)./sqrt(2)

FM = Pideal ./(k.*Pideal + (solidity.*Cdo./8))
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