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Thermal Performance of Stratospheric Airships During Ascent and Descent

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On the basis of some assumptions and simplifications, a thermal model is developed to describe the heat transfer behavior of stratospheric airships. The Runge–Kutta method is adopted to solve the governing equations. Considering the airship flight state, control style, and working environment, some of its basic characteristics and thermal performances are investigated. The variations in the temperatures of the film, internal helium, and internal air of the airship with altitude during its ascent and descent are obtained. The results reveal that among the influencing factors, the airship velocity, air filling, and air venting seriously affect its thermal performance. When the airship ascends in the adiabatic situation or the venting velocity reaches a specific value above 11 km, the temperature of the film could drop to its damage point, which would seriously influence the airship operation.

Nomenclature

A = effective area of absorbing radiation, m^2
B = net lift, N
C_{DV} = drag coefficient
C_p = specific heat, $\mathrm{J/(kg \cdot K)}$
C_{pa} = specific heat for internal air, $\mathrm{J/(kg \cdot K)}$
C_{pf} = specific heat for film, $\mathrm{J/(kg \cdot K)}$
C_{ph} = specific heat for helium, $\mathrm{J/(kg \cdot K)}$
D = day of a year (1 January is 1, 31 December is 365)
d_m = correction of sun–Earth distance
Gr = Grashof number
g = acceleration of gravity, $\mathrm{kg/(s \cdot m^2)}$
h = heat transfer coefficient
I = solar radiation flux, $\mathrm{J/m^2}$
m = mass, kg
m_{add} = added mass, kg
m_s = net mass of the airship structure, kg
Nu = Nusselt number
n = relative atmosphere mass
P = pressure, Pa
Pr = Prandtl number
p_t = atmospheric transmittance
R = gas constant, $\mathrm{J/(kg \cdot K)}$
r_e = reflectivity
Q = heat, J
S = area, m^2
S_{ref} = characteristic area, m^2
T = temperature, K
T_{bb} = blackball temperature, K
t = time, s or h
U = velocity, m/s
V = volume, m^3
X = day angle of the sun, rad
z = altitude, m
α = effective absorptivity
γ = ratio of specific heats, C_p/C_v
Δ = difference used as prefix
δ = declination of the sun, rad
δ = thickness, m
ε = effective emissivity
θ = solar zenith angle, rad
λ = thermal conductivity, $\mathrm{W/(m \cdot K)}$
ρ = density, $\mathrm{kg/m^3}$
σ = Stefan–Boltzmann constant
φ = latitude, rad
ω = hour angle of the sun, rad

Subscripts

$a-f$ = internal air and film
$a-h$ = internal air and helium
air = internal air
ao = ambient air
$\mathrm{ao}-f$ = ambient air and film
f = film
he = helium
$h-f$ = helium and film
0 = initial state

I. Introduction

With the development of aerospace science and technology, the use of special space and solar energy resources has attracted scientists' attention [1,2]. As a high-altitude platform, stratospheric airships have wide application, especially in communication, broadcasting, remote sensing, scientific research, etc. The performance of the stratospheric airship during its ascent and descent is affected by its structure, control system, and ambient parameters. In flight, the helium and air inside the airship will expand or be compressed, corresponding to the variation in ambient pressure. Meanwhile, the ambient temperature, airship velocity, and solar radiation mainly influence the heat transfer of the airship. As a result, they will affect the net lift of the airship and therefore the controlling performance. The thermal design is of primary importance for achieving a better performance for a high-altitude airship. In the past

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