SR555: Heat Transfer in Space Applications
Aerodynamic Heating-II

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Aerodynamic Heating

- **We have obtained these equations:**
  - **Full differential eq.:**

(1) $$\frac{dT_w}{dt} - \frac{h}{t_{skin} C_{skin} \rho_{skin}} \left(T_r - T_w \right) + \frac{\varepsilon \sigma T_w^4}{t_{skin} C_{skin} \rho_{skin}} = 0$$

  - **Differential eq. without radiation:**

(2) $$\frac{dT_w}{dt} - \frac{h}{t_{skin} C_{skin} \rho_{skin}} \left(T_r - T_w \right) = 0$$

  - **Quartic equation:**

(3) $$\varepsilon \sigma T_w^4 - h\left(T_r - T_w \right) = 0$$

Numerical solutions are required (equations 1–3)

  - **Equation without radiation:**

(4) $$T_r = T_{w,e}$$

Aerodynamic Heating

- **We will use Eq. (2) to obtain some results:**

$$\text{(2)} \quad \frac{dT_w}{dt} - \frac{h}{t_{skin} C_{skin} \rho_{skin}} \left(T_r - T_w \right) = 0$$

Problem:

Consider the flight of a surface-to-air missile (SAM) at constant altitude (15000 m) without significant radiation heating.

The SAM is uniformly accelerated to 1500 m/s from rest. It maintains speed and the aerodynamic heating reaches equilibrium. The missile then decelerates to zero velocity. The missile nose cone angle is 30^{o}, length is 30 cm, and recovery factor c = 0.6.

Analysis:

- three phases: uniform acceleration, constant velocity, and uniform deceleration

Aerodynamic Heating

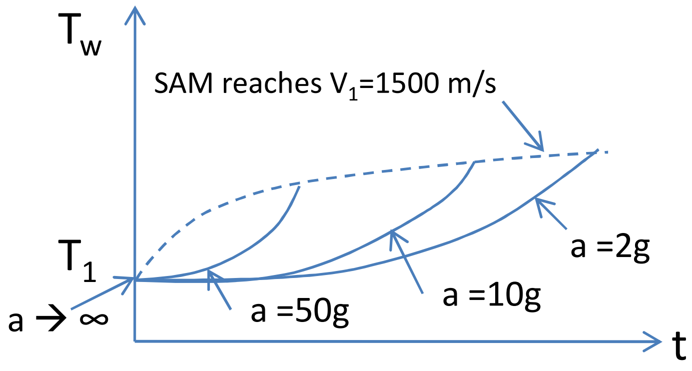
- **We will use Eq. (2) to obtain some results:**

$$\textcircled{2}\quad \frac{dT_w}{dt} - \frac{h}{t_{skin} C_{skin} \rho_{skin}} (T_r - T_w) = 0$$

Phase I: For uniform acceleration period, V_1 = at; initial condition: $T_w = T_1$

Eq. (2) can be solved numerically using appropriate formula for h. We get T_w = *f*(t)

Some results:



Larger acceleration leads to smaller T_w

V_1

Aerodynamic Heating

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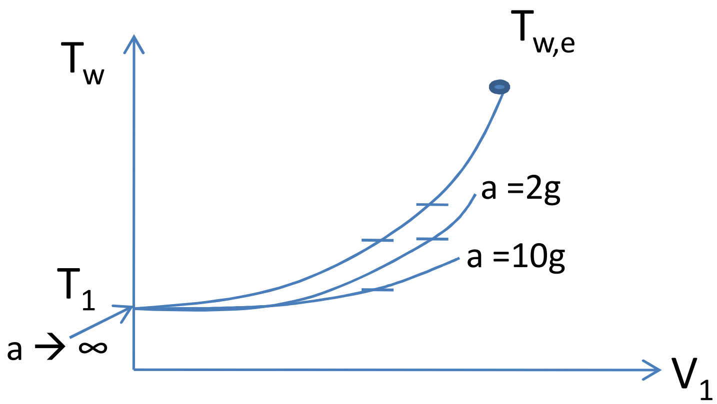

Since radiation is neglected, $T_{w,e}$=T_g

Greater temperature lag at larger acceleration

Aerodynamic Heating

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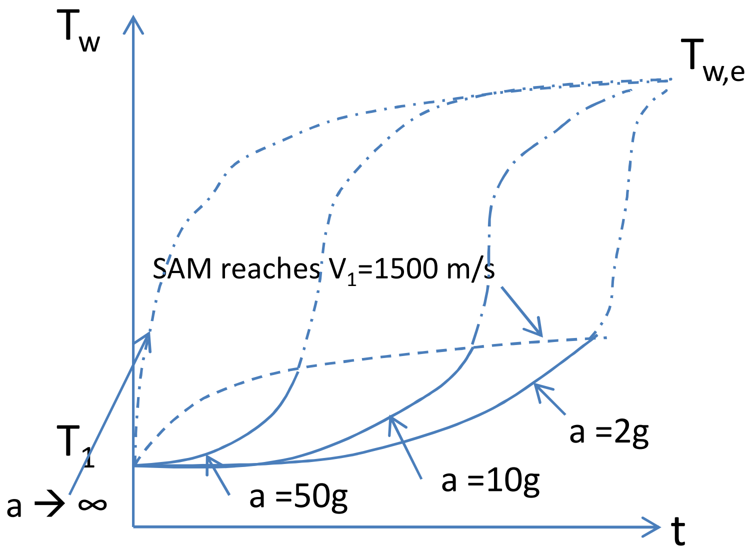
Phase II: For constant velocity period, h and Tg are no longer functions of time

Some results:



Aerodynamic Heating

- **We will use Eq. (2) to obtain some results:**

$$\frac{dT_w}{dt} - \frac{h}{t_{skin} C_{skin} \rho_{skin}} (T_r - T_w) = 0 \quad (2)$$

Phase III: For uniform deceleration

Some results: