THE STUDY OF SURFACE DUST CONCENTRATION OF SATELLITE IN FAIRING SEPARATION

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Abstract

The explosion process is usually used for satellite releasing during fairing separation. Explosion products are not allowed to be leaked from the detonating tube connecting two parts of the fairing during the fairing separation process. This paper predicts the contamination of the explosion products falling on the satellite surface during fairing separation on the ground and in space in case of the computer simulation by using the theory of explosion gaseous dynamics and the basic theory of aerosol mechanics.

Key words satellite surface, explosion, jet flow, aerosol, the amount of dust

I. Mathematics Model

Explosion products are not allowed to be leaked from the detonating tube connecting two parts of the fairing during the fairing separation process. General speaking, the detonating tube filling with dynamites should withstand certain pressure, but the tube might be broken if the pressure in explosion process exceeds the limit or the detonating tube used is not good enough. To find out the maximum contamination, we suppose some broken holes are on the different part of the tube in explosion, from which dust with plume flow is emitted from the tube and the satellite surface is contaminated.

1. Explosion

Fig. 1 is a cross-section of cylinder dynamite package. Suppose explosion starts at point \(O(R=0)\), as the results of reaction, chemical dynamites are almost turned into explosive products at the moment with high temperature and high pressure, the explosive wave—a compress gaseous layer is formed in the front of explosive gas. All energy of chemical explosion is almost turned into the energy of explosive waves.

Suppose explosion starts at time \(t=0\) and point \(O(R=0)\). At the time \(t\), the dynamites package is divided into react area \((0< R < R_0)\) and non-reacted area \((R_0 \leq R \leq R_w)\) separated by an explosive wave front—a thin chemical reaction area. The reaction area is composed by gaseous explosive products with high temperature and high pressure, i.e. explosive waves, and they
represent the impact waves spreading in the package. On the wave front, the state parameters change suddenly. At the point A on the explosive wave, the state parameters are: pressure \( P = \rho(R, t) \); density \( \rho = \rho(R, t) \); velocity \( u = u(R, t) \). When \( t > t_w \), there is a gaseous explosive zone \( 0 < R < R_w \) and a compression medium zone \( R_w < R < R_c \). According to the Quality Equilibrium Theory, Momentum Equilibrium Theory and one-dimension undefined differential flow equation:\(^4\):

\[
\begin{align*}
\frac{\partial \rho}{\partial t} + u \frac{\partial \rho}{\partial R} + \rho \frac{\partial u}{\partial R} + \frac{\rho u}{R} &= 0 \\
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial R} + \frac{1}{\rho} \frac{\partial P}{\partial R} &= 0 \\
\frac{P}{\rho^2 RT} &= \phi(\rho), \text{in the air, } \phi(\rho) = 1
\end{align*}
\]

(1.1)

Initial conditions: the velocity at point O, \( u(0, 0) = 0 \), on the explosive wave front,

\[
\begin{align*}
P(R_d, 0) &= P_d, \quad \rho(R_d, 0) = \rho_d, \\
u(R_d, 0) &= u_d
\end{align*}
\]

To calculate the initial value, we consider following closed-equation:

\[
\begin{align*}
u_d &= \left(1 - \frac{\rho_w}{\rho_d}\right) D \\
P_d &= P_w + \rho_w u_d D \\
P_d &= \rho_d \cdot RT_d
\end{align*}
\]

(1.2)

where

\( D \): the velocity on the explosive wave front;
\( T \): absolute temperature;
\( T_d \): absolute temperature on the detonation wave front;
\( R \): gaseous constant.

Subscript \( D \) means the value on the explosive wave front, and subscript \( w \) means the value on the surface of cylinder package.

After calculating, the equations for the explosive wave front can be obtained:

\[
\begin{align*}
\rho_d &= \frac{k_1 + 1}{k_1} \rho_w \\
P_d &= P_w + \frac{\rho_w}{k_1 + 1} D \\
u_d &= \frac{D}{k_1 + 1}
\end{align*}
\]

(1.3)