A NOTE ON INTERNAL BALLISTICS WITH COMPOSITE CHARGE

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In the present note, it has been pointed out that under certain conditions the internal ballistics of orthodox guns during the first stage of burning of a composite charge can be obtained with the help of Hunt-Hinds tables.

Internal ballistics of orthodox guns using composite charges has been discussed by Kapur[1], Aggarwal[2]. Venkatesan and Patni[3], Kapur[4] made an attempt to deduce the internal ballistics in case of composite charges with help of Hunt-Hinds[5] (1951) tables by equivalent charge method, but as pointed out by him, there is error in the solution because of inherent error in the estimation of the form-factor of the equivalent charge. In another paper Kapur[6] observed that if the composite charge consists of two components both in the form of tube the solution for the first stage of burning can be obtained by Hunt-Hinds tables. We shall, however, see in the present note that when the components of the composite charge are of some specific sizes and shapes the internal ballistics for the first stage of burning can be obtained with the help of Hunt-Hinds tables. In passing we would like to mention that in the present discussion we have taken the ratios of specific heats of gases produced by the components to be all equal, since in practice this will be found to be almost true.

Fundamental equations

With the assumption about specific heats and with notations of Kapur[4] the equations for the first stage of burning can be written as below :

$$\sum_{i=1}^{n} F_i \ C_i \ Z_i = p \left[A\,(x+l) - \sum_{i=1}^{n} C_i \ Z_i \left(b_i - \frac{1}{\delta_i} \right) \right] + \tfrac{1}{2}\,(\gamma - 1)\,\omega_1\, v^2 \qquad (1)$$

$$D_i \ \frac{df_i}{dt} = -\,\beta_i \ p ; \ (i = 1, 2, 3, \ \ldots\ldots\ldots\ldots\ldots\ldots , n) \qquad (2)$$

$$Z_i = (1 - f_i)\,(1 + \theta_i\, f_i) \ ; \ (i = 1, 2, 3, \ \ldots\ldots\ldots\ldots , n) \qquad (3)$$

$$\omega_1 \, v \frac{dv}{dx} \equiv \omega_1 \ \frac{dv}{dt} = A \ p \ . \qquad (4)$$

To calculate the ballistics for this stage of burning the above equations are to be integrated with given initial conditions. The values of various variables at the end of this stage of burning will correspond to $f_1 = 0$. In the next section we demonstrate that under certain condition the solution of the above equations can be obtained with help of Hunt-Hinds tables, *Main result*

From the equations in (2) we have

$$\frac{D_1}{\beta_1}\frac{df_1}{dt} = \frac{D_2}{\beta_2}\frac{df_2}{dt} = \cdots\cdots\cdots\cdots = \frac{D_n}{\beta_n}\cdot\frac{df_n}{dt}$$

which on integration, subject lo the condition that f_i's are 1 to start with, give

$$\frac{D_1}{\beta_1}(1-f_1) = \frac{D_2}{\beta_2}(1-f_2) = \cdots\cdots\cdots\cdots = \frac{D_n}{\beta_n}(1-f_n)$$

or

$$\frac{D_1}{\beta_1}(1-f_1) = \frac{D_i}{\beta_i}(1-f_i)\,; \qquad (i = 2, 3, \ldots\ldots\ldots, n) \tag{5}$$

Now

$$Z = (1-f_i)(1+\theta_i f_i)$$

$$= \frac{D_1/\beta_1}{D_i/\beta_i}(1-f_1)\left[1+\theta_i\left\{1-\frac{D_1/\beta_1}{D_i/\beta_i}(1-f_1)\right\}\right] \quad \text{by (5)}$$

$$= \frac{D_1/\beta_1}{D_i/\beta_i}\left[1+\theta_i\left(1-\frac{D_1/\beta_1}{D_i/\beta_i}\right)\right](1-f_1)\left[1+\frac{\frac{D_1/\beta_1}{D_i/\beta_i}\,\theta_i}{1+\theta_i\left(1-\frac{D_1/\beta_1}{D_i/\beta_i}\right)}\,f_1\right] \tag{6}$$

t us introduce

$$K_i = \frac{D_1/\beta_1}{D_i/\beta_i}\,; \qquad (i = 1, 2, 3, \ldots\ldots\ldots, n) \tag{7}$$

and assume that

$$\theta_1 = \frac{K_i\,\theta_i}{1+\theta_i(1-K_i)}\,, \qquad (i = 2, 3, \ldots\ldots\ldots, n) \tag{8}$$

so from (6) we have

$$Z_i = K_i\left\{1+\theta_i(1-K_i)\right\}(1-f_1)(1+\theta_1 f_1)$$

or with (8)

$$Z_i = \frac{K_i^2\,\theta_i}{\theta_1}Z_1\,, \qquad (i = 2, 3, \ldots\ldots\ldots\ldots, n) \tag{9}$$

With (9) and noting that $K_1 = 1$, equation (1) can be written as

$$\frac{Z_1}{\theta_1} \sum_{i=1}^{n} F_i\ C_i\ K^2_i\ \theta_i = p \left[A\ (x+l) - \frac{Z_1}{\theta_1} \sum_{i=1}^{n} C_i \left(b_i - \frac{1}{\delta_i} \right) K^2_i\ \theta_i \right]$$

$$+ \tfrac{1}{2}\ (\gamma - 1)\ \omega_1\ v^2$$

Now we write

$$\frac{1}{\theta_1} \sum_{i=1}^{n} F_i\ C_i\ K_i^2\ \theta_i = F\ C \tag{10}$$

$$\frac{1}{\theta_1} \sum_{i=1}^{n} C_i \left(b_i - \frac{1}{\delta_i} \right) K^2_i\ \theta_i = C \left(b - \frac{1}{\delta} \right) \tag{11}$$

Therefore the above equation reduces to

$$FC\ Z_1 = p \left[A\ (x+l) - CZ_1 \left(b - \frac{1}{\delta} \right) \right] + \tfrac{1}{2}\ (\gamma - 1)\ \omega_1\ v^2 \tag{12}$$

With the above equation we take (4) and first equations $(i = 1)$ in (2) and (3) *i.e.*,

$$D_1 \frac{df_1}{dt} = -\beta_1\ p \tag{13}$$

$$Z_1 = (1 - f_1)\ (1 + \theta_1 f_1) \tag{14}$$

$$\omega_1\ v \frac{dv}{dx} = \omega_1 \frac{dv}{dt} = Ap$$

Thus to calculate the ballistics for the first stage of burning it is sufficient to integrate (12), (13), (14) and (4) with given initial conditions provided (8) holds. The Hnnt-Hinds tables give the solution of exactly these system of equations (12), (13), (14) and (4). Now equation (8) sets up relations between the size and shape of successive components and those of the first component. Thus if the size and shape of the components are connected by this relation (8), the internal ballistics for the first stage of burning can be obtained with help of Hunt-Hinds tables. We note that if all the θ_i's are zero, necessarily (8) holds. Thus Kapur's[6] observation that ballistics for the first stage of burning are obtainable by Hunt-Hinds tables, in case all the components are in the form of tubes, is only a particular case of (8). The values of various ballistic variables at the end of the first stage of burning mill correspond to $f_1 = 0$.

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