MEASUREMENT OF THE POLYTROPY INDEX FOR GAS-DETONATION PRODUCTS

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This method for \( \gamma \) is based on measurement of \( D_2/D_1 \) (ratio of velocities of incident and reflected waves) for two colliding detonation waves under conditions where one can neglect the three-dimensional structure of the reaction zone in the incident wave. The collision of these effectively one-dimensional detonation waves is described by the solution for the collision of a detonation wave with an absolutely rigid wall for the strong-wave approximation [1,2]. This approximation may give a substantial error in \( \gamma \) for a gas detonation, where the ratio of \( P_0 \) (initial pressure) to \( P_1 \) (pressure in detonation wave) is 0.05-0.2. We therefore deduce the relation of \( \gamma \) to \( D_2/D_1 \) without neglecting \( P_0 \) relative to \( P_1 \).

The conservation and other equations for the incident wave are

\[ p_0 D_1 = p_1(D_1 - u_1), \quad p_1 - p_0 = p_0 D_1 u_1, \]

\[ \frac{p_1}{p_0} = \frac{1}{\gamma_1} + 1 = \frac{p_1}{p_0}. \] (1)

For the reflected wave (on the assumption that \( \gamma_1 = \gamma_2 = \gamma \) the conservation laws give

\[ p_2 D_2 = p_2(D_2 + u_2), \quad p_2 - p_0 = p_2(D_2 + u_2) u_2, \]

\[ \frac{p_2}{p_0} = \frac{p_2(1 - \gamma) + p_1(1 + \gamma)}{p_1(1 + \gamma) + p_2(1 - \gamma)}. \] (2)

Here \( p \) and \( u \) are respectively the density and mass velocity, while subscripts 0, 1, and 2 relate to the initial mixture, the incident wave, and the reflected wave. In Eqs. (1) and (2) we make the substitutions

\[ d = \frac{D_2}{D_1} + 1, \quad \frac{1}{\gamma} = \frac{1 + \gamma}{\gamma}, \quad \gamma = \frac{p_0}{p_1}. \] (3)

to get

\[ d(1 + \frac{1 - \gamma}{\gamma}) = \frac{\gamma(1 - \gamma)}{4} - \frac{\gamma(1 - \gamma)^2}{16} + 1 = 0. \] (4)

This may be put as

\[ ay^2 + by + c = 0. \] (5)

If the terms in \( \pi^2 \) are neglected, the coefficients are

\[ a = 2d^2 - 5d + 1 + \pi(d^2 - 1), \]

\[ b = 4d^2 - 6d + 1 + \pi(d^2 - 4d^2 - 1), \]

\[ c = d(2d - 1) - \pi(2d - 1) d. \] (6)

Figure 1 shows solutions to Eq. (5) for \( \pi \) positive and for the most probable range of \( D_2/D_1 \) (0.3-0.5) for various \( \pi = p_2/p_1 \); the upper curve corresponds to the solution for a strong detonation wave.

This may be used as a nomogram with the observed \( D_2/D_1 \) and \( p_2/p_1 \) to deduce \( \gamma \).

Figure 2 shows the apparatus used to measure \( \gamma \). The spiral 2 ignites the gas mixture in tube 1; the conversion of the combustion to a detonation is accelerated [3] by the spiral 3. Tube 1 is connected to the symmetrically placed tube 4; part 5 is made of glass and has an internal diameter of 16 mm. The middle part is viewed by a ZhFR-1 camera [4, 5].

The gas mixtures had compositions and initial pressures far from the detonation limits. The recordings were as shown in Fig. 3; \( D_2/D_1 \) is deduced from the angles \( \alpha \) and \( \beta \) as follows:

\[ \frac{D_2}{D_1} = \frac{a + b/2}{c}. \] (6)

Table 1 gives results for various mixtures, including acetylene-oxygen containing argon, for which \( \gamma = 1.87 \), it being assumed that the \( \gamma \) for this case would be larger than that for a mixture without argon. The \( p_0/p_1 \) for these mixtures were as follows: \( 2H_2 + O_2, 0.05 \), \( CH_4 + 2O_2, 0.02 \), \( C_2H_2 + 2SO_2, 0.02 \), and \( C_2H_2 + 2SO_2 + 2.5Ar \) showed an increase in \( D_2/D_1 \) as \( p_0 \) decreased, which evidently reflects the influence of the wave structure [6-8]. Inhomogeneity produces a complex pattern in the reflected waves near the point of reflection, the lines of propagation of the fronts being bent (Fig. 3a). There is hardly any effect on \( D_2/D_1 \) for \( p_0 > 500 \text{ mm Hg} \), and so \( \gamma \) was deduced from the

Table 1

<table>
<thead>
<tr>
<th>( p_0 )</th>
<th>( 2H_2 + O_2 )</th>
<th>( CH_4 + 2O_2 )</th>
<th>( C_2H_2 + 2SO_2 )</th>
<th>( C_2H_2 + 2SO_2 + 2.5Ar )</th>
</tr>
</thead>
<tbody>
<tr>
<td>915</td>
<td>--</td>
<td>0.422±0.005</td>
<td>0.388±0.012</td>
<td>0.412±0.008</td>
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<tr>
<td>880</td>
<td>0.42±0.01</td>
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<td>--</td>
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<tr>
<td>760</td>
<td>0.42±0.01</td>
<td>0.42±0.02</td>
<td>0.389±0.007</td>
<td>0.414±0.008</td>
</tr>
<tr>
<td>600</td>
<td>0.45±0.02</td>
<td>0.42±0.02</td>
<td>0.389±0.009</td>
<td>0.428±0.008</td>
</tr>
</tbody>
</table>
Fig. 3. Recordings of colliding detonation waves: a) $2H_2 + O_2$, $p_0 = 880$ mm Hg, 16 mm tube; b) $C_2H_2 + 2.5O_2$, $p_0 = 300$ mm Hg, 16 mm tube.