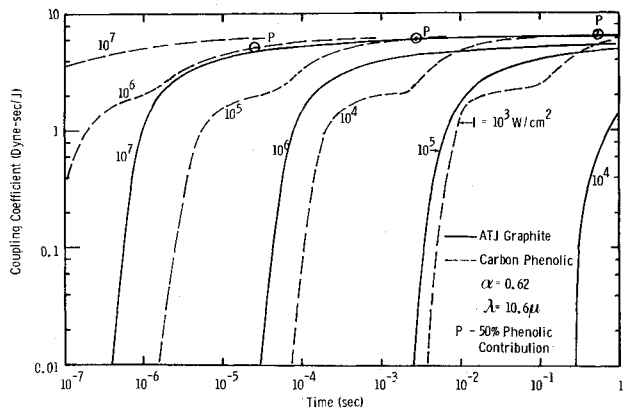

Fig. 1 Time history of coupling coefficients for ATJ graphite and carbon phenolic.

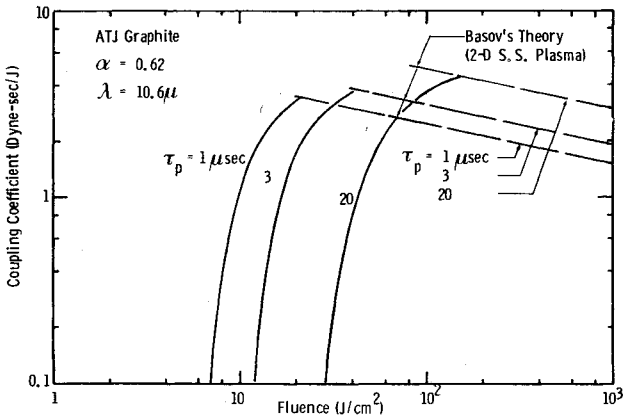

Fig. 2 The coupling coefficient of ATJ graphite as a function of fluence for given pulse times.

For carbon phenolic, the coupling coefficients as a function of time are presented in Fig. 1. For a given laser intensity, the coupling coefficients for carbon phenolic are observed to rise at an earlier time than that of the graphite because the vaporization of phenolic begins to take place at a few hundred degrees Celsius. As shown in Fig. 1, the coupling coefficients rise after the vaporization temperature of phenolic has been reached and eventually approach the asymptotic steady-state value of approximately 6 dyn-s/J. The change in curvature on the curve is due to the characteristic pyrolysis reaction at low temperature. In addition, along the coupling coefficient curves for 10^4–10^6 W/cm^2 the locations P where the phenolic contributes 50% of the coupling coefficient values have been indicated. The corresponding locations on the 10^3 W/cm^2 curve are to the right of the plot (or at times greater than 1 s). Hence, for the carbon phenolic considered here, the contributions to the coupling coefficient from the phenolic are significant.

As shown in Fig. 3, the coupling coefficients for carbon phenolic are presented as a function of fluence for pulse times of 1, 3, and 20 μs. Again, the coupling coefficients for the two-dimensional steady-state plasma are also given as reference, and the locations A and B indicate the fluence levels where the phenolic contributions are 90% and 20%, respectively. For the pulse time considered here, the coupling coefficient rises rapidly to 1-2 dyn-s/J then gradually increases to about 4 dyn-s/J over a wide range of fluence (approximately 1-10 J/cm^2) and finally approaches the steady-state value at higher fluence. In terms of the coupling coefficient, the present (single pulse) results show that for low intensity (10^3–10^5 W/cm^2) and long pulses the effect of phenolic is important in providing the laser-induced impulse to a carbon phenolic surface. Now consider a multiple pulse train where the interpulse time is long compared with the characteristic thermal diffusion time. For these multiple pulse

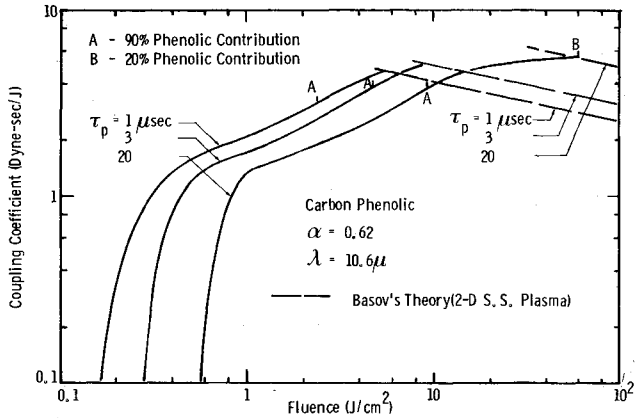

Fig. 3 The coupling coefficient of carbon phenolic as a function of fluence for given pulse times.

trains, one expects that the coupling coefficient, which is dominated by phenolic contribution, would decrease after the first pulse, because a portion of the phenolic near the surface has been depleted while the carbon char surface is intact.

Acknowledgment

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Improvements in the Combustion Driving Technique for Shock Tubes

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RECENT work at this university, involving measurement of the rates of formation of nitric oxide from combustion mixtures led to the need for a shock tube producing post-

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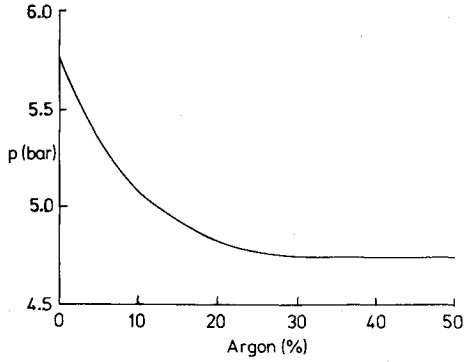

Fig. 1 Variation of minimum total precombustion gas pressure required to burst diaphragm with argon concentration—expressed in this and later figures as a percentage of driver gas not chemically involved in combustion.

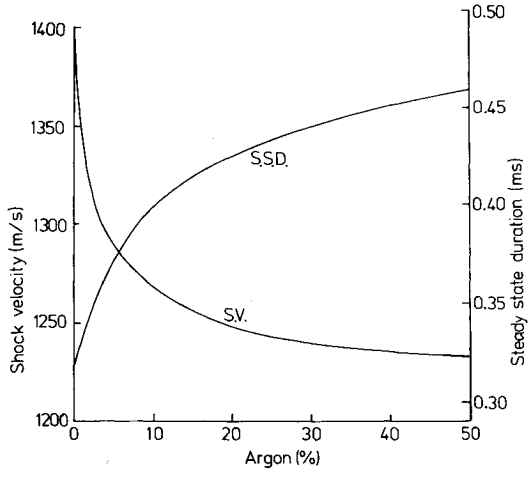

Fig. 2 Variation of shock velocity and steady-state duration as a function of argon concentration.

shock pressures of 10-15 atm at temperatures of 1900-2400 K in test gases containing around 90 mol % of argon. A 12.7-cm-diam incident wave shock tube employing constant volume combustion of hydrogen/oxygen mixtures to burst the diaphragms and drive the shocks had previously been used in the study of soot formation under similar conditions, but severe shock attenuation reduced the usefulness of the equipment. This problem has been stated before to be a disadvantage of the combustion driving method,[1,2] but it was felt that the possible benefits of a prolonged steady state behind a combustion-driven shock wave justified the research described here.

It was felt that the problem was a result of very large heat losses from the 92% hydrogen/8% oxygen driver mixtures to the walls of the driver section and the inserted ignition system, starting at ignition. The high thermal conduction losses from the hydrogen produce changes in sound speed and specific heat ratio of the driver gas. An initial series of experiments was carried out to find a combination of diaphragm type and precombustion gas pressure which would produce at least a brief steady-state period behind the incident shock wave. The combination of a plain, unscored, 0.9-mm "half-hard" aluminum sheet diaphragm with an initial gas pressure of 5.75 bar absolute, and observation at a point 2 m from the diaphragm, was found to satisfy this criterion. This produced a steady-state duration of $\sim 0.3 \times 10^{-3}$ s at 2200 K and 12 bar, corresponding to a gas reaction time of $\sim 1.05 \times 10^{-3}$ s.

A series of measurments was then undertaken of the precombustion pressure of driver gas mixture required to cause bursting of the diaphragms with an increasing proportion of the "excess" hydrogen replaced by argon (Fig. 1). A set of measurements was then undertaken at each of a number of mixture concentrations to provide a more precise measure of the variation of shock velocity and steady-state duration with argon concentration. The results of these measurments are summarized in Figs. 2 and 3.

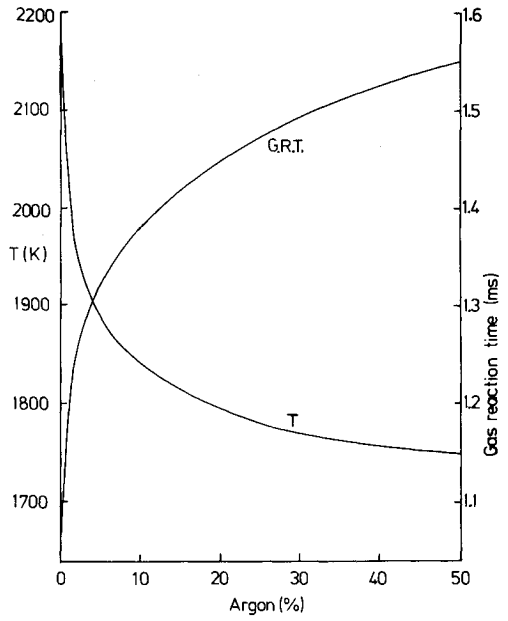

Fig. 3 Variation of post-shock temperature and gas reaction time with argon concentration.

The most notable feature of these figures is the rapid variation of shock velocity, and hence post-shock temperature and pressure and steady state duration with the substitution of relatively small concentrations of argon. The trend toward a steady value of shock velocity with increasing argon concentration suggests the balancing of the effect of added argon at any given temperature in lowering sound speed and increasing specific heat ratio against its effect in reducing thermal conductivity and hence increasing temperature and sound speed.

These argon driver mixtures, combined with the aluminium diaphragms, produce reasonably reproducible shock behavior and the standard deviation in post-shock temperatures, for a large set of similar shocks, was ~40 K, where the mean is ~1900 K. The technique as applied to chemical kinetic studies has the considerable advantage of producing a further degree of freedom in the production of specific temperatures and pressures. It permits, for example, the production of a range of temperatures at constant pressure by variation of only two parameters, the argon concentration and the test gas pressure, and produces relatively strong shocks by a simple, cheap and uncomplicated method, reproducibly, and much more safely than the use of the necessary pressures of cold hydrogen as driver gas would allow. We consider that the development of this method marks a considerable advance in the applicability of combustion driven shock tubes.

Acknowledgment

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