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Nonstationary Combustion Waves

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ABSTRACT

We consider a simple model of combustion wave in a one-dimensional approach. As it known, narrowness of reaction zone allows us to obtain a nonlinear integral equation on burning velocity. The wave velocity varies slowly near the combustion limit. This makes it possible to reduce this equation to an ordinary differential equation of the first order. We term it a quasi-stationary equation (QSE). QSE solutions describe an approach to uniform propagation of the wave above the limit. Below the limit, these solutions are suitable for a slow stage of the wave quenching that determines characteristic time of the process. According to QSE, wave susceptibility diverges as the limit is approached. This results in onset of chaotic pulsating of the wave velocity and its magnitude. Maximal deviations in pulsating are comparable in scale to corresponding mean values - as at fully developed turbulence. Low frequencies prevail in their spectra. The low-frequency peak narrows with parameter displacement toward the limit. The wave numerical simulation shows a good qualitative agreement with the QSE solutions. At the same time, the QSE is not valid in the case of small diffusivity: the wave becomes nonstationary before the limit. From numerical simulation, we see a transition to chaotic modes through a sequence of period doublings. Then, frequent transitions between chaotic modes occur, and the spectrum tends from discrete to continuous form. However, sometimes it returns to concentration near several "lines". We treat this as a manifestation of frequency locking. If parameters correspond to such a concentration, intermittency is observed in time evolution of the wave velocity. Just above the limit, a fully developed chaos takes place. In the sublimit region of the parameters, time of wave quenching grows (toward the limit) with jumps. The jumps occur each time when a number of flashes before the quenching increases from n to n+1. However, the "average" time growth appears to be in accordance with a power low, which the QSE predicts. Without heat loss, parameter displacement into a domain of oscillatory instability gives a following picture: After period doublings and a relatively narrow interval occupied by chaotic motion, relaxation oscillations of the wave velocity are seen. Their peak-to peak and periods increase with the displacement. Traveling pulse quenching differs from that of the combustion wave.