DYNAMICS OF FLAME OSCILLATIONS IN NARROW SOLID FUEL SAMPLES WITH HEAT LOSSES[1]

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The emergence of oscillatory (diffusive-thermal) instabilities due to the Poincaré–Andronov–Hopf bifurcation is well known in combustion of solid fuels. One-dimensional pulsations in the propagation of combustion waves were found in experiments on Self-Propagating High-Temperature Synthesis, combustion of thermites and gunpowders [1–3].

The influence of heat-losses on the flame dynamics in narrow samples of energetic material is investigated numerically. The model is considered in a one-dimensional form with the one-step irreversible Arrhenius reaction mechanism. A typical C-shaped response curve is found for the dependence of the flame-propagation velocity on the heat-loss parameter, with solutions along the lower branch of slower flames being always unstable. It is found that a part of the upper branch of the C-shaped response curve is also unstable and the Poincaré–Andronov–Hopf bifurcation takes place at a certain value of heat-loss intensity even if the steady state solution is stable under the corresponding adiabatic conditions. The numerical simulations show that an increase in heat-losses induces, for sufficiently high Zel'dovich numbers, the Feigenbaum's cascade of period doubling bifurcations after which a chaotic dynamics is setting in.

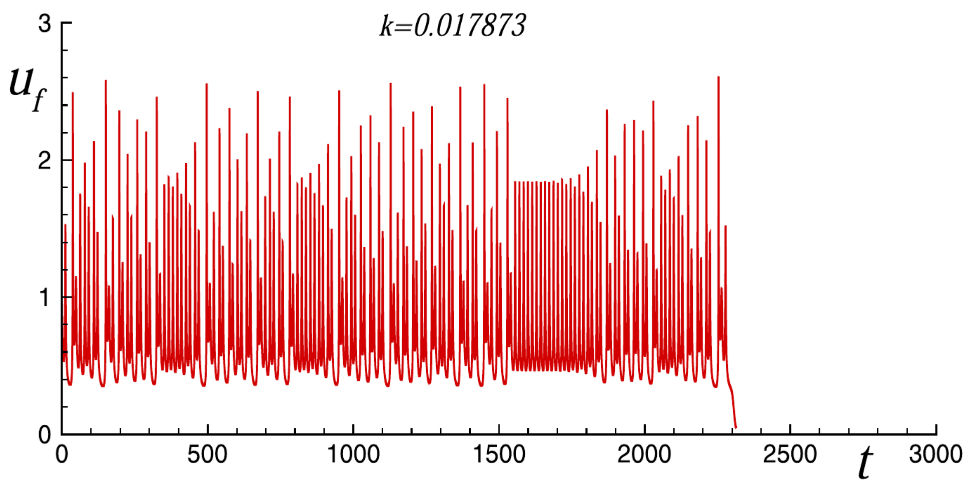

Fig. 1. Oscillations of instant velocity of combustion wave for Zel'dovich number 8 and certain value of the heat loss parameter illustrating the flame quenching via chaotic pulsations.

The chaotic dynamics precedes the flame extinction occurring for the further increase of the heat-loss parameter which, nevertheless, remains significantly lower than the steady extinction limit dictated by the C-shaped response curve. The flame quenching via the chaotic oscillations is illustrated in Fig. 1. Apparently, the parametric dependence of the extinction time in these cases is also irregular with appreciable disparities in magnitude. Finally, the intermittency effect is detected slightly below the extinction limit with irregular dynamics alternating by apparently periodic stages. These results may be important for the flammability limits theory and practical fire safety applications.

REFERENCES

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