Resonant Behavior in a Periodically Forced Non-Isothermal Oregonator

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Oscillatory phenomena are common in Nature and observed in a great variety of biological processes such as the Krebs cycle, the circadian clock, and the cell cycle[1]. A classic example of a chemical oscillator is the Belousov-Zhabotinsky reaction[2, 3], which has become a prime example for non-linear, out-of-equilibrium chemical dynamics. Natural oscillators are normally subject to both periodic and stochastic external perturbations in the values of environmental physical variables, such as light irradiation and temperature. Such fluctuations are expected to modulate, modify, or even determine and entrain the behavior of nonlinear systems[4].

Nonisothermal chemical oscillators are poorly studied systems because chemical oscillations are conventionally studied under isothermal conditions. Coupling chemical reactions with heat generation and consumption in a nonisothermal oscillatory system can lead to a highly nontrivial nonlinear dynamic behavior. For this study we considered the three-variable Oregonator model with the temperature incorporated as a variable (not a parameter) thus adding an energy balance to the set of equations. The effect of the temperature on reaction rates is included through the temperature-dependent reaction rate coefficients (Arrhenius law). To model a continuous operation in a lab environment, the system was subjected to external forcing through the coolant temperature and infrared irradiation. By conducting numerical simulations and parametric studies, we have found that the system is capable of resonant behavior exhibiting induced oscillations. Our findings indicate that an external source of heat (e.g., via an infrared light emission diode) can be used to induce a Hopf bifurcation under resonant conditions in an experimental BelousovZhabotinsky reactor [5].

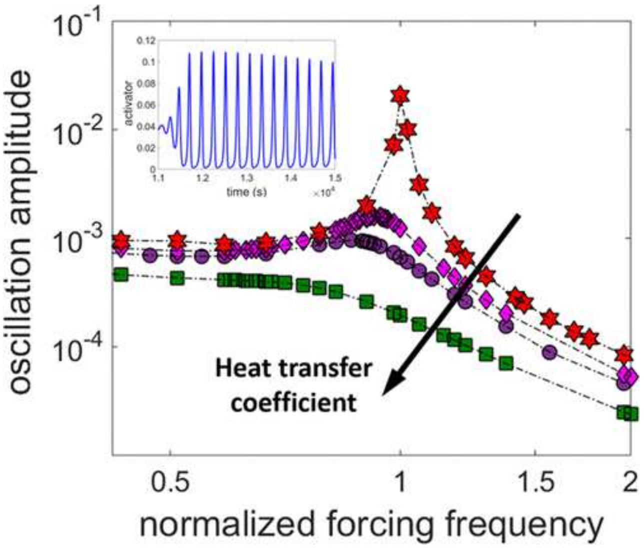

Fig. 1. Resonant curves for some values of the heat transfer coeffiecient.

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