

Teymour, F.; Ray, W. H.

Chaos, intermittency and hysteresis in the dynamic model of a polymerization reactor.
(English) [Zbl 0744.58047](#)

[Chaos Solitons Fractals 1, No. 4, 295-315 \(1991\).](#)

Summary: Experimental evidence of sustained oscillatory behavior for a lab-scale polymerization reactor was presented previously, and confirmed in modelling studies. A modified mathematical model for this process describing full scale reactors was later analyzed in detail. Bifurcation theory and numerical continuation techniques were used in locating complex dynamic structures. Results pointed to the possibility of chaotic behavior in the dynamics of the model analyzed. This paper is aimed at a more detailed investigation of the chaotic regime. The structure of the strange attractor is first illustrated and characterized using different methods (e.g. Poincaré sections, Lyapunov exponents, successive iterate maps,...). Numerical experiments in the chaotic regime are then conducted. These reveal the presence of numerous periodic windows with odd period oscillations; in some cases, chaos is seen to disappear and re-emerge through the intermittency mechanism. Also a mechanism of chaotic transition through hysteresis and preperiodicity is observed and is shown to be related to a tangent bifurcation similar to that leading to intermittency. It is believed to constitute a possible new universal route to the emergence of chaos.

MSC:

- [37C70](#) Attractors and repellers of smooth dynamical systems and their topological structure Cited in 4 Documents
- [82D60](#) Statistical mechanical studies of polymers
- [82D75](#) Nuclear reactor theory; neutron transport
- [58Z05](#) Applications of global analysis to the sciences

Keywords:

[polymerization reactor](#); [strange attractor](#); [Poincaré sections](#); [Lyapunov exponents](#); [successive iterate maps](#); [period oscillations](#); [chaos](#)

Full Text: [DOI](#)

References:

- [1] Jaisinghani, R.; Ray, W.H., On the dynamic behavior of a class of homogeneous continuous stirred tank polymerization reactors, *Chem. engng sci.*, **32**, 811-825, (1977)
- [2] Schmidt, A.D.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—I. isothermal solution polymerization in a CSTR, *Chem. engng sci.*, **36**, 1401-1410, (1981)
- [3] Hamer, J.W.; Akramov, T.A.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—II. nonisothermal solution homopolymerization and copolymerization in a CSTR, *Chem. engng sci.*, **36**, 1897-1914, (1981)
- [4] Schmidt, A.D.; Clinch, A.B.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—III. an experimental study of multiple steady states in solution polymerization, *Chem. engng sci.*, **39**, 419-432, (1984)
- [5] Teymour, F.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—IV. dynamic stability and bifurcation analysis of an experimental reactor, *Chem. engng sci.*, **44**, 1967-1982, (1989)
- [6] Teymour, F.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—V. experimental investigation of limit cycle behavior for vinyl acetate polymerization, *Chem. engng sci.*, (1991), submitted for publication · [Zbl 0744.58047](#)
- [7] Teymour, F.; Ray, W.H., The dynamic behavior of continuous polymerization reactors—VI. complex dynamics in full scale reactors, *Chem. engng sci.*, (1991), submitted for publication · [Zbl 0744.58047](#)
- [8] Lorenz, E.N., Deterministic nonperiodic flow, *J. atmos. sci.*, **20**, 130-141, (1963) · [Zbl 1417.37129](#)
- [9] Kahlert, C.; Rössler, O.E.; Varma, A., ()
- [10] Jörgensen, D.V.; Aris, R., On the dynamics of a stirred tank with consecutive reactions, *Chem. engng sci.*, **38**, 45-53, (1983)
- [11] Retzloff, D.G.; Chan, P.C.H.; Chicone, C.; Offin, D.; Mohamed, R., Chaotic behavior in the dynamical system of a continuous stirred tank reactor, *Physica D*, **25**, 131-154, (1987) · [Zbl 0623.58035](#)
- [12] Chan, P.C.H.; Retzloff, D.G.; Mohamed, R.; Berdouzi, B.; Chicone, C.; Offin, D., The dynamic behavior and chaos for two

- parallel reactions in a continuous stirred tank reactor, *Chem. engng comm.*, 57, 105-138, (1987)
- [13] Mankin, J.C.; Hudson, J.L., Oscillatory and chaotic behaviour of a forced exothermic chemical reaction, *Chem. engng sci.*, 39, 1807-1814, (1984)
- [14] Kevrekidis, I.G.; Aris, R.; Schmidt, L.D., The stirred tank forced, *Chem. engng sci.*, 41, 1549-1560, (1986)
- [15] Caneba, G.T.; Crossey, M.J., Chaos in a periodically perturbed CSTR, *Chem. engng comm.*, 51, 1-18, (1987)
- [16] McKarnin, M.A.; Schmidt, L.D.; Aris, R., Response of nonlinear oscillators to forced oscillations: three chemical reaction case studies, *Chem. engng sci.*, 43, 2833-2844, (1988)
- [17] Hasegawa, S.; Watanabe, N.; Matsubara, M., Bifurcations and chaos appearing in a periodically controlled CSTR, *Chem. engng comm.*, 30, 35-53, (1984)
- [18] Kahlert, C.; Rössler, O.E., Chaos as a limit in a boundary value problem, *Z. naturforsch.*, 39, 1200-1203, (1984) · [Zbl 0588.58046](#)
- [19] Hudson, J.L.; Rössler, O.E.; Killory, H., A four-variable chaotic chemical reaction, *Chem. engng comm.*, 46, 159-166, (1986)
- [20] Killory, H.; Rössler, O.E.; Hudson, J.L., Higher chaos in a four-variable chemical reaction mode, *Phys. lett. A*, 122, 341-345, (1987)
- [21] Gray, P.; Scott, S.K., Sustained oscillations and other exotic patterns of behaviour in isothermal reactions, *J. phys. chem.*, 89, 22-32, (1985)
- [22] Nandapurkar, P.J.; Hlaváček, V.; Van Rompay, P., Chaotic behaviour of a diffusion-reaction system, *Chem. engng sci.*, 41, 2747-2760, (1986)
- [23] Rathousky, J.; Puszynski, J.; Hlaváček, V., Experimental observation of chaotic behavior in CO oxidation in lumped and distributed catalytic systems, *Z. naturforsch.*, 35, 1238-1244, (1980)
- [24] Razón, L.F.; Chang, S-M; Schmitz, R.A., Chaos during the oxidation of carbon monoxide over platinum—experiments and analysis, *Chem. engng sci.*, 41, 1561-1576, (1986)
- [25] Wicke, E.; Onken, H.U., Statistical fluctuations of conversion and temperature in an adiabatic fixed-bed reactor for CO oxidation, *Chem. engng sci.*, 41, 1681-1686, (1986)
- [26] Wicke, E.; Onken, H.U., Periodicity and chaos in a catalytic packed bed reactor for CO oxidation, *Chem. engng sci.*, 43, 2289-2294, (1988)
- [27] Sheintuch, M.; Schmidt, J., Bifurcations to periodic and aperiodic solutions during ammonia oxidation on a pt wire, *J. phys. chem.*, 92, 3404-3411, (1988)
- [28] Herzog, H.; Ebeling, W.; Schulmeister, Th., Nonuniform chaotic dynamics and effects of noise in biochemical systems, *Z. naturforsch.*, 42, 136-142, (1987)
- [29] Tomita, K.; Daido, H., Possibility of chaotic behavior and multi-basins in forced glycolytic oscillations, *Phys. lett. A*, 79, 133-137, (1980)
- [30] Olsen, L.F., Chaos in an enzyme reaction, *Nature*, 267, 177-178, (1977)
- [31] Olsen, L.F., Studies of the chaotic behaviour in the peroxidase-oxidase reaction, *Z. naturforsch.*, 34, 1544-1546, (1979)
- [32] Olsen, L.F., An enzyme reactions with a strange attractor, *Phys. lett. A*, 94, 454-457, (1983)
- [33] Olsen, L.F., Effects of periodic and stochastic perturbations on oscillations and chaos in a model of the peroxidase-oxidase reaction, *Z. naturforsch.*, 40, 1283-1288, (1985)
- [34] Diem, C.B.; Hudson, J.L., Chaos during the electrodisolution of iron, *A.I.Ch.E.jl*, 33, 218-224, (1987)
- [35] Lev, O.; Wolffberg, A.; Sheintuch, M.; Pismen, L.M., Bifurcation to periodic and chaotic motions in anodic nickel dissolution, *Chem. engng sci.*, 43, 1339-1353, (1988)
- [36] Schmitz, R.A.; Graziani, K.R.; Hudson, J.L., Experimental evidence of chaotic states in the Belousov-Zhabotinskii reaction, *J. chem. phys.*, 67, 3040-3044, (1977)
- [37] Lamba, P.; Hudson, J.L., Experimental evidence of multiple oscillatory states in a continuous reactor, *Chem. engng comm.*, 32, 369-375, (1985)
- [38] Turner, J.S.; Roux, J-C.; McCormick, W.D.; Swinney, H.L., Alternating periodic and chaotic regimes in a chemical reaction—experiment and theory, *Phys. lett. A*, 85, 9-12, (1981)
- [39] Roux, J-C., Experimental studies of bifurcations leading to chaos in the belousov-Zhabotinsky reaction, *Physica D*, 7, 57-68, (1983)
- [40] Turner, J.S., Complex periodic and nonperiodic behavior in the Belousov-zhabotinski reaction, *Adv. chem. phys.*, 55, 205-217, (1984)
- [41] Teymour, F.A., ()
- [42] Shimada, I.; Nagashima, T., A numerical approach to ergodic problem of dissipative dynamical systems, *Prog. theor. phys.*, 61, 1605-1616, (1979) · [Zbl 1171.34327](#)
- [43] Schuster, H.G., Deterministic chaos, (1984), Physik Weinheim
- [44] Pomeau, Y.; Manneville, P., Intermittent transition to turbulence in dissipative dynamical systems, *Commun. math. phys.*, 74, 189-197, (1980)
- [45] Tresser, C.; Coulet, P.; Arneodo, A., On the existence of hysteresis in a transition to chaos after a single bifurcation, *J. phys. lett.*, 41, L243-246, (1980)

- [46] Testa, J.; Perez, J.; Jeffries, C., Evidence for universal chaotic behavior of a driven nonlinear oscillator, *Phys. rev. lett.*, 48, 714-717, (1982)
- [47] Mercader, I.; Massaguer, J.M.; Net, M., Hysteresis in a transition to chaos, *Phys. lett. A*, 149, 195-199, (1990)

This reference list is based on information provided by the publisher or from digital mathematics libraries. Its items are heuristically matched to zbMATH identifiers and may contain data conversion errors. It attempts to reflect the references listed in the original paper as accurately as possible without claiming the completeness or perfect precision of the matching.