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On a Nonlinear and Non-Ideally Excited Tank

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Abstract: In this work, we revisited and investigated the nonlinear parametric resonance of free surface oscillations of fluid inside a tank excited by a non-ideal power source with limited power supply. Numerical analysis of nonlinear dynamics is presented as phase portrait diagrams, power spectrum and maximum Lyapunov exponents to determine the regions in which the resonant sloshing vibrations have a chaotic or periodic behavior. we also present an Optimal Linear Feedback Control (OLFC) and a State Dependent Riccatti Equation (SDRE) Control design that can both reduce to the chaotic movement to a stable condition. The (OLFC) technique is based on Lyapunov stability theory and optimal quadratic linear control (LQR) and has the characteristic of separating nonlinearity from the system and applying feedforward control feedback control. The (SDRE) control method (SDRE) has as main characteristic for calculating the LQR gain the variable state matrix

Keywords: Non-ideal power sources. Parametric resonance. Nonlinear dynamics. Control Design's

1. Introduction

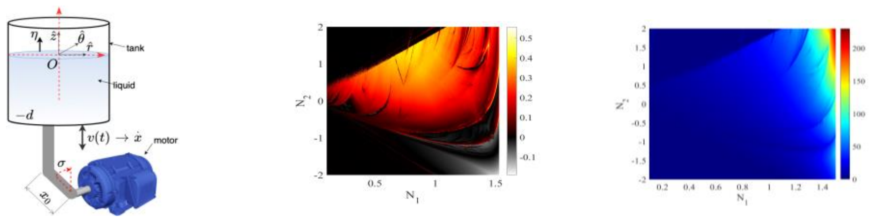
Sloshing inside a tank excited by a non-ideal power source has diverse applications in engineering sciences as in aerospace and nuclear fields. The excitation of the system analyzed by this work is limited by the characteristics of the energy source and its dependency on the vibrating system. We present a model based on [1, 2], composed by a tank of radius R, partially filled with a Newtonian fluid, parametrically excited by an electric motor (Fig. 1(a)). The nonlinear dynamics of system can be represented by equations below:

$$\left.\begin{cases} \frac{dp_1}{d\tau} = -\alpha p_1 - (\beta + AE - 2)q_1 + BMp_2; \quad \frac{dp_2}{d\tau} = -\alpha p_2 - (\beta + AE - 2)q_1 + BMp_1 \\ \frac{dq_1}{d\tau} = -\alpha q_1 + (\beta + AE + 2)p_1 + BMq_2; \quad \frac{dq_2}{d\tau} = -\alpha q_1 + (\beta + AE + 2)p_2 + BMq_1; \quad \frac{\beta}{d\tau} = N_2 - N_1\beta - \mu(p_1q_1 + p_2q_2) \end{cases}\right\} \quad (1)$$

where, τ: slow time; p_1, q_1, p_2, q_2: dominant modes amplitudes; α:liquid coefficient of additional viscous damping forces of liquid; β: tuning parameter related to motor frequencies. A and B: constant coefficients dependent on tank diameter and depth of the filled liquid; E and M: energy and angular momentum of fluid vibrations in the fundamental modes. N_1: constant of linear static performance curve of the motor; N_{2}.: natural frequency of the fundamental free surface oscillations; μ: natural frequency and physical characteristics of the moto and $E = E_1 + E_2$, $E_n = 12\left(p_n^2 + q_n^2\right)$ and $M = p_1q_2 + p_2q_1$.

2. Results and Discussion

The computational numerical method for solution used was the fourth order Runge-Kutta implicit with integration step of h=0.001 and time of $t=10^5$ and transient time of 40% of total time. We assume the parameters are $\alpha = 0.8, A = 1.112, B = -1.531, N2, = -0.25, \mu = 4.5$ and initial conditions to be equal to $p1(0) = q1(0) = 1.0, p2(0) = q2(0) = 1.0, \beta(0) = 0$, adapted from [1].



(a) (b) (c)

Fig. 1. (a) Schematic diagram of the system composed by a partially filled tank, excited by a motor. (b)Lyapunov exponent λ in range $N_1 \in [0.05,1.5] \times N_2 \in [-2.0,2.0]$ (c) Energy total in range $N_1 \in [0.05,1.5] \times N_2 \in [-2.0,2.0]$

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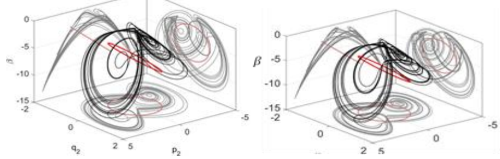
Fig. 1(b) shows the behavior of maximum Lyapunov exponent (λ) with $N_1 \in [0.05,1.5] \times N_2 \in [-2.0,2.0]$. For negative values of λ the system is periodic, for positive values of λ the system is chaotic. Fig. 1(c) illustrates the results for the dimensionless total power[2]. For high values of N_1 and N_2 the rate of change of the total energy is zero. Inside the regions where N_1 and N_2 have intermediate values the total power oscillates around zero but there is no constant period. OLFC and SDRE techniques based on [3] were applied to an orbit was defined with a Fourier Series as $u(i)(t) = a_0 + a_1 cos(\omega t) + b_1 sin(\omega t)$ and they have excellent agreement according to Fig 2(a) and (b).



(a) **(b)**

Fig 2 Results using a) OLFC ,b) SRDE

3. Conclusion

This work shows that the OLFC and SDRE strategy applied to the presented mathematical model reduced the chaotic movement of the system to a periodic one. The Fig. 2 illustrates the effectiveness of the control strategy to this interaction fluid-electric motor problem. Future works include sensibility analysis.

References

1. H. A. NAVARRO, J. M. BALTHAZAR, T. S. KRASNOPOL'SKAYA, A. Y. SHVETS, AND F. R. CHAVARETTE, Remarks on parametric surface waves in a nonlinear and non-ideally excited tank, *J. Vib. Acoust. Trans. ASME*, vol. 134, no. 4, pp. 1–6, Aug. 2012. https://doi.org/10.1115/1.4005844
2. T. S. KRASNOPOL'SKAYA AND A. Y. SHVETS, Energy Transfer Between Hydrodynamical Systems and Excitation Machines of Limited Power Supply, Proc. ENOC -St. Petersburg, Russia, June 30–July 4 , 2008.
3. A. M. TUSSET, BALTHAZAR J. M. ; BASSINELO , D. ; PONTES B.R. ; FELIX J. L. P. Statements on chaos control designs, including a fractional order dynamical system, applied to a MEMS comb-drive actuator. *Nonlinear Dynamics*, v. 69, p. 1837-1857, 2012. https://doi.org/10.1007/s11071-012-0390-6

The Existence of Absolutely Continuous Invariant Measures for q-Deformed Unimodal Maps

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Abstract: In this paper, we describe the various types of deformation schemes inspired by Heine and Tsallis in reference of q-deformed physical system related to the quantum group structures and the statistical mechanics. We discuss the dynamics of deformed unimodal maps in particular q-Logistic map and q-Gaussian map. Further we show that numerically, there exists a set of the parameter values with positive measure, for which these deformed maps admits absolutely continuous invariant probability measure with respect to the Lebesgue measure.

Keywords: acip, deformed map, deformed Logistic map, deformed Gaussian map.

References

[1] BALADI V, VIANA M: Strong stochastic stability and rate of mixing for unimodal maps. *Annales scientifiques de l'Ecole normale supérieure* 1996, **29**(4):483-517.
[2] BANERJEE S, PARTHASARATHY R: A q-deformed logistic map and its implications. *Journal of Physics A: Mathematical and Theoretical* 2011, **44**(4)):3-23.
[3] DE MELO W, VAN STRIEN S: One-dimensional dynamics. *Springer Science & Business Media* 2012.
[4] JACKSON F H: XI.—on q-functions and a certain difference operator. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 1909, **46**(2):253-81.
[5] JAGANATHAN R, SINHA S: A q-deformed nonlinear map. *Physics Letters A* 2005, **338**(3-5):277-87.
[6] JAKOBSON M V: Absolutely continuous invariant measures for one-parameter families of one-dimensional maps. *Communications in Mathematical Physics* 1981, **81**(1):39-88.
[7] KELLER G: Exponents, attractors and Hopf decompositions for interval maps. *Ergodic Theory and Dynamical Systems* 1990, **10**(4):717-44.
[8] KOZLOVSKY O S: Structural stability in one-dimensional dynamics, 1998.
[9] NOWICKI T, VAN STRIEN S: Invariant measures exist under a summability condition for unimodal maps. *Inventiones mathematicae* 1991, **105**(1):123-36.
[10] THUNBERG H: Periodicity versus chaos in one-dimensional dynamics. *SIAM review* 2001, **43**(1):3-0.