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Analysis of nonlinear fractional Duffing oscillator using Homotopy analysis method (HAM)

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Abstract

We investigated the analytical solutions of the forced Duffing oscillator with fractional order derivatives given by the equation

$$\begin{cases} D^{\alpha}u + \delta D^{\beta}u + \rho u + \mu u^3 = \lambda \sin \omega t, & t \in [0, \infty) \\ u(0) = a, \;\; D^{\beta}u(0) = b, & a, b \neq 0, \text{ are real or complex constants} \end{cases} \tag{1}$$

where D denote the Caputo derivative, u is the displacement function, $\delta > 0$ is the damping factor, $m = [\alpha]$, $0 < \beta \leq 1$, $1 < \alpha \leq 2$, $\mu > 0$, $\rho > 0$, $\lambda > 0$ is amplitude of vibration, ω is the frequency.

We obtained the solution to the above equation by converting it to its augmented system with the same order and applied Homotopy Analysis Method (HAM) with a proper choice of the initial conditions. We observed that the solution of the fractional order case coincides with that of an integer case for $\alpha = 2$ and $\beta = 1$. Finally, the accuracy properties were demonstrated with an example.

Keywords: Fractional differential equations; Homotopy analysis method; Duffing Oscillator; Mittag-Leffler function.

Category: **Mathematical physics.**