Performance Analysis of Swelling Elastomer Seals in Petroleum Applications

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Abstract

The development of conventional controllers fundamentally depends upon availability of the exact mathematical model of the dynamic system. However, most of the real world systems are harnessed with unknown nonlinearities and dynamic uncertainties. Therefore, controllers designed with imprecise knowledge result in poor performance. This reason has motivated the development of adaptive controllers that handle dynamic uncertainties with adaptive adjustment of controller parameters on run-time.

On the other hand, soft computing techniques such as artificial neural networks closely resemble to adaptive systems in terms of architecture and learning capabilities. In fact, artificial neural networks have been extensively used as adaptive inverse controllers. However, the majority of available neuro-adaptive inverse controllers are associated with two significant problems. First, the neural networks are trained with the conventional gradient descent backpropagation learning algorithms that suffer from slow convergence and frequently trap at the local minima of the error cost function. Second, these adaptive control techniques do not establish mathematical foundations for error convergence and closed-loop stability conditions. Instead, they assume the convergence and stability based on the Certainty Equivalence Principle, which is not a realistic assumption. These problems make the performance of the adaptive controller unreliable.

A neuro-adaptive inverse control technique for single-input single-output dynamic plants that overcomes the aforementioned problems is proposed and discussed in this research work. A Lyapunov function based backpropagation learning algorithm for neural network training has been presented. The proposed backpropagation algorithm guarantees fast convergence and assures single global minimum with adaptive adjustment of the network parameters. Moreover, an adaptive inverse control architecture has been presented that uses two Lyapunov function neural networks in a unified framework. In this scheme, one neural network acts as the inverse dynamics controller whereas the other functions as an estimator to calculate the control command. The error convergence and closed-loop stability of the inverse controller have been proved with the Lyapunov Stability Theory. Furthermore, the controller performance has been studied with four simulation examples and two laboratory-scale experimental setups. These case studies show that tracking of the continuous trajectories is achieved and local minima trapping is not observed. The simulation and experimental results validate theoretical findings.