# Simulation of the Hysteresis Model for the MR Fluid Damper Using a Hybrid Evolutionary Algorithm

**Xue Xiaomin**
*Department of Civil Engineering, Xi'an Jiaotong University, Xi'an, China*

**Wu Xiaohong**
*School of Aerospace, Xi'an Jiaotong University, Xi'an, China*

**Sun Qing**
*Department of Civil Engineering, Xi'an Jiaotong University, Xi'an, China*

**Zhang Ling**
*School of Aerospace, Xi'an Jiaotong University, Xi'an, China*

(Received 18 July 2013; accepted 14 May 2014)

The developed MF dampers can be used for diverse applications, including structural vibration mitigation, shock absorption, and vibration control in various systems. This paper has firstly investigated the mechanical characteristics of the self-made MR damper through experimentation. Based on the test data, the damper is found to possess nonlinear hysteresis. Usually, various models, especially the Bouc-Wen model, are proposed to interpret the complex characteristics which have the capability to capture behavior of a wide class of hysteretic systems. However, the Bouc-Wen model consists of a set of multi-unknown parameters that need to be estimated simultaneously. It is a burdensome task to effectively identify the exact values of the parameters. In view of this, this paper proposes a novel hybrid evolutionary algorithm combining Genetic Algorithm with Particle Swarm Optimization (GA-PSO). By using the GA-PSO, the optimized result would be more effective and accurate than the traditional one, because it overcomes the drawbacks of low-speed convergence in GA and local optimization in PSO. Finally it is verified through a large amount of experimental data, which can estimate the multi parameters in the Bouc-Wen model efficiently and precisely. Also suggested are the implications of the present study on other nonlinear hysteretic models or other complex mathematical models.

## 1. INTRODUCTION

Hysteresis is a memory-dependent, non-linear behavior in which the system output is not only dependent on the instantaneous input, but also on the past history of the input.[1,2] This type of inelastic behavior is encountered in many engineering fields, such as biology, electronics, ferroelectricity, mechanics, magnetism, etc. For efficient description of such inelastic systems, over the past years many mathematical models have been proposed for use in practical applications involving characterization of systems, identification or control.[3] The Bouc-Wen model[4] is widely used to describe systems with hysteresis and non-linear behavior, especially in civil and mechanical engineering. In this model, restoring force is related to the system viscous deformation through a first-order differential equation, which has a series of undefined parameters. By assigning proper values to these parameters, the response of the model will be in keeping with the actual behavior of hysteretic systems. Thus, it is pivotal to select an appropriate optimization algorithm to perform the task of parameter identification.

Recently, optimization techniques have been most widely applied to estimate the parameters of the Bouc-Wen model that characterize hysteretic behavior, such as Gauss-Newton and modified Gauss-Newton,[5] Levenberg-Marquardt,[6,7] Genetic Algorithms,[4,8] Particle Swarm Optimization,[9,10] etc. Traditional techniques (Gauss-Newton and Levenberg-Marquardt, etc.) are adequate to identify favorable parameters in the case of simple problems, since a good initial value can be easily obtained based on previous information. With regard to complex problems, favorable parameters cannot be identified with ease by local search algorithms due to the difficulties of setting the initial value.[8] As a result, parameter identification techniques based on intelligent algorithms are arousing more interest in modeling and parameter identification. For example, Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) have robust features and are suitable for solving multi-objective problems. However, these methods also have their limitations. GA generally requires a large number of function evaluations whose convergence speed is quite slow because the evolution of solutions depends on evolutionary operators.[11] According to this situation, Liu focuses on the problem of premature convergence in GA, and proposes an adaptive GA based on population diversity.[10] Chang proposes an improved real-coded GA for parameter estimation of nonlinear systems to directly implement the programming operations.[12] Aine states that parameters of evolutionary algorithms should be appropriately