

ABSTRACT

This study optimizes the design of a meandering-type Magnetorheological (MR) valve for truck damper applications through a predictive modeling approach that integrates an Artificial Neural Network (ANN) with Chaotic Particle Swarm Optimization (CPSO). The ANN model was developed to predict magnetic flux density based on Finite Element Method (FEM) simulation data, achieving high accuracy ($MSE = 0.00002$; $R^2 = 0.9997$). The outer radial zone demonstrated the best predictive performance compared to the outer annular and inner radial zones, highlighting the ANN's capability in modeling the nonlinear relationship between geometric parameters, electric current, and magnetic flux. This model was employed as the fitness function in a multi-objective optimization using CPSO, aiming to minimize viscous pressure drop while maximizing total pressure drop. Optimal objective weights of 0.6 and 0.1 were assigned to these goals, resulting in an optimal configuration with an annular gap of 1.20 mm and a radial gap of 0.38 mm, which are considered feasible for fabrication. The design produced a viscous pressure drop of 0.9674 MPa, a yield pressure drop of 6.6397 MPa, and a total pressure drop of 7.6071 MPa, corresponding to a maximum damping force of 7,150.6 N and a control range of 6.863, indicating high adaptability for truck damper applications. CPSO exhibited stability and computational efficiency with an objective function value of -0.1802 ± 0.0000 across ten runs and a convergence time of 13–16 minutes. The proposed ANN–CPSO predictive approach proved to be effective, efficient, and robust in producing MR valve designs with optimal damping performance for truck suspension systems.

Keyword: Magnetorheological valve, Artificial Neural Network (ANN), Chaotic Particle Swarm Optimization (CPSO), design optimization, truck damper.

INTISARI

Penelitian ini mengoptimalkan desain *Magnetorheological (MR) valve* tipe *meandering* untuk aplikasi peredam truk melalui pendekatan model prediktif yang menggabungkan *Artificial Neural Network (ANN)* dan *Chaotic Particle Swarm Optimization (CPSO)*. Model ANN dikembangkan untuk memprediksi kerapatan fluks magnetik berdasarkan data simulasi *Finite Element Method (FEM)*, dengan tingkat akurasi tinggi (MSE 0,00002; R^2 0,9997). Zona radial luar menunjukkan performa prediktif terbaik dibandingkan zona annular luar dan radial dalam, menunjukkan ANN dalam memodelkan hubungan nonlinier antara parameter geometri, arus listrik, dan fluks magnetik. Model ini digunakan sebagai *fitness function* dalam optimasi *multi-objective function* melalui CPSO, dengan tujuan meminimalkan *pressure drop viscous* dan memaksimalkan *pressure drop total*. Bobot objektif optimal sebesar 0,6 dan 0,1 masing-masing ditetapkan untuk tujuan tersebut, menghasilkan konfigurasi optimal berupa *annular gap* 1,20 mm dan *radial gap* 0,38 mm yang dinilai mudah untuk difabrikasi. Desain ini menghasilkan *pressure drop viscous* 0,9674 MPa, *yield* 6,6397 MPa, dan total 7,6071 Mpa dengan gaya redaman maksimum 7.1506 N, serta rentang kendali 6,863, yang menunjukkan adaptabilitas tinggi untuk aplikasi peredam truk. CPSO menunjukkan kestabilan dan efisiensi komputasi dengan nilai fungsi objektif $-0,1802 \pm 0,0000$ dalam sepuluh *run* dan waktu konvergensi 13–16 menit. Pendekatan prediktif ANN-CPSO terbukti efektif, efisien, dan *robust* dalam menghasilkan desain *MR valve* dengan kinerja redaman optimal untuk sistem peredam truk.

Kata kunci: *Magnetorheological valve*, *Artificial Neural Network (ANN)*, *Chaotic Particle Swarm Optimization (CPSO)*, optimasi desain, peredam truk.