ABSTRACT

Off-road vehicles require front bumpers capable of absorbing impact energy effectively to protect vehicle components and passengers. This study aims to design a custom front bumper for off-road vehicles and analyze structural performance using Finite Element Analysis (FEA) approach and integrate it with Artificial Neural Network (ANN) to accelerate prediction and design optimization. The research method includes custom bumper design using CAD software, crash test simulation using ANSYS Explicit Dynamics with variations in impact velocity (5-25 m/s), materials (mild steel and aluminum), and plate thickness (2.5 mm, 3 mm, 3.5 mm, 4 mm, 5 mm, and 6 mm). FEA simulation results including peak force, maximum stress, Energy Absorbed (EA), and deformation were used as datasets to train the ANN model with Levenberg-Marquardt algorithm. FEA simulation results showed that mild steel material with 4 mm thickness produced optimal performance, indicated by Crash Force Efficiency (CFE) values of 69-79% and favorable bumper mass, while aluminum 5 mm provided a lighter alternative with CFE of 60-68%. The developed ANN model was able to predict bumper structural performance with very high accuracy, indicated by coefficient of determination (R^2) values above 0.96 for the training, validation, and testing datasets, with prediction deviation less than 5%. FEA-ANN integration proved effective for predicting bumper structural performance without repeated simulations, thus saving time and costs in the design process. This research contributes to the development of simulation-based and machine learning automotive component design methodology.

Keywords: *Custom Front Bumper, Crash Test Simulation, Finite Element Analysis (FEA), Artificial Neural Network (ANN)*

INTISARI

Kendaraan *off-road* memerlukan *bumper* depan yang mampu menyerap energi benturan dengan baik untuk melindungi komponen kendaraan dan penumpang. Penelitian ini bertujuan untuk merancang *bumper* depan *custom* untuk kendaraan *off-road* dan menganalisis performa struktur menggunakan pendekatan *Finite Element Analysis* (FEA) serta mengintegrasikannya dengan *Artificial Neural Network* (ANN) untuk mempercepat prediksi dan optimasi desain. Metode penelitian meliputi perancangan *bumper custom* menggunakan *software* CAD, *simulasi crash test* menggunakan ANSYS *Explicit Dynamics* dengan variasi kecepatan benturan (5-25 m/s), material (*mild steel* dan aluminium), dan ketebalan plat (2,5 mm, 3 mm, 3,5 mm, 4 mm, 5 mm, dan 6 mm). Data hasil simulasi FEA berupa *peak force*, *maximum stress*, *Energy Absorbed* (EA), dan deformasi digunakan sebagai dataset untuk melatih model ANN dengan algoritma *Levenberg-Marquardt.* Hasil simulasi FEA menunjukkan bahwa material *mild steel* dengan ketebalan 4 mm menghasilkan performa yang optimal, hal ini berdasarkan atas hasil nilai *Crash Force Efficiency* (CFE) yang mencapai 69-79% serta pertimbangan massa *bumper*. Sedangkan aluminium 5 mm memberikan alternatif lebih ringan dengan CFE 60-68%. Model ANN yang dikembangkan mampu memprediksi performa struktur *bumper* dengan tingkat akurasi sangat tinggi, ditunjukkan oleh nilai koefisien determinasi (R^2) di atas 0,96 pada data *training*, *validation,* dan *testing*, dengan deviasi prediksi kurang dari 5%. Integrasi FEA-ANN terbukti efektif untuk memprediksi performa struktur *bumper* tanpa perlu melakukan simulasi berulang, sehingga menghemat waktu dan biaya dalam proses desain. Penelitian ini memberikan kontribusi dalam pengembangan metodologi desain komponen otomotif berbasis simulasi dan *machine learning*.

Kata Kunci: *Bumper* Depan *Custom*, *Crash Test Simulation*, *Finite Element Analysis* (FEA), *Artificial Neural Network* (ANN)