

INTISARI

Ban non-pneumatik atau *non-pneumatic tire* (NPT) dikembangkan sebagai alternatif ban pneumatik untuk mengatasi permasalahan seperti kebocoran, keausan tidak merata, dan keterbatasan umur pakai. Komponen utama yang menentukan performa NPT adalah struktur *spoke*, yang berfungsi sebagai elemen penopang beban dan pengendali deformasi. Struktur hexagonal digunakan sebagai *spoke* karena kemampuannya dalam mendistribusikan beban secara merata serta memberikan keseimbangan antara kekakuan dan fleksibilitas. Namun, performa struktur ini sangat dipengaruhi oleh konfigurasi geometrinya, khususnya jumlah batas lapisan penyusun sel, yang berperan penting dalam jalur transfer beban, kekakuan radial, dan distribusi tegangan pada NPT.

Penelitian ini bertujuan menganalisis pengaruh variasi batas lapisan struktur hexagonal terhadap karakteristik pembebanan *spoke* NPT melalui pendekatan numerik dan eksperimental. Tiga variasi desain dianalisis, yaitu tipe A (3 batas lapisan), tipe B (4 batas lapisan), dan tipe C (5 batas lapisan). Analisis numerik dilakukan menggunakan metode elemen hingga (*Finite Element Method / FEM*) pada perangkat lunak ANSYS Workbench 2021 R2 dengan pemodelan material *hyper-elastic*. Validasi dilakukan melalui uji tekan statis menggunakan *Universal Testing Machine* (UTM) terhadap prototipe *spoke* berbahan *Thermoplastic Polyurethane* (TPU) yang diproduksi menggunakan teknologi *Fused Deposition Modelling* (FDM), dengan kondisi perpindahan vertikal sebesar 3 mm.

Hasil penelitian menunjukkan bahwa peningkatan jumlah batas lapisan pada struktur *hexagonal* meningkatkan kekakuan radial dan gaya reaksi yang dihasilkan, namun juga cenderung meningkatkan konsentrasi tegangan maksimum. Berdasarkan hasil simulasi dan eksperimen, desain *spoke* tipe C menunjukkan kompromi paling optimal antara kekakuan, deformasi, distribusi tegangan, dan karakteristik getaran dibandingkan tipe lainnya. Temuan ini memberikan dasar penting bagi pengembangan dan optimasi desain ban non-pneumatik berbasis struktur hexagonal untuk meningkatkan performa dan keandalan struktural pada aplikasi kendaraan.

Kata kunci: ban non-pneumatik (NPT), *hexagonal*, *spoke*, analisis statik, metode elemen hingga, uji tekan

ABSTRACT

Non-pneumatic tires (NPT) are developed as an alternative to conventional pneumatic tires to overcome issues such as punctures, uneven wear, and limited-service life. One of the key components determining NPT performance is the spoke structure, which functions as a load-bearing element and deformation controller. Hexagonal structures are commonly used as spokes due to their ability to distribute loads uniformly while providing a balanced combination of stiffness and flexibility. However, the performance of this structure is strongly influenced by its geometric configuration, particularly the number of layer boundaries within the hexagonal cells, which plays a crucial role in load transfer paths, radial stiffness, and stress distribution in NPTs.

This study aims to analyse the effect of variations in the number of layer boundaries in hexagonal spoke structures on the loading characteristics of NPT spokes through numerical and experimental approaches. Three design variations were investigated: Type A with three-layer boundaries, Type B with four-layer boundaries, and Type C with five-layer boundaries. Numerical analysis was conducted using the Finite Element Method (FEM) implemented in ANSYS Workbench 2021 R2 with hyper-elastic material modelling. Experimental validation was performed through static compression tests using a Universal Testing Machine (UTM) on spoke prototypes made of Thermoplastic Polyurethane (TPU) fabricated via Fused Deposition Modelling (FDM), under a vertical displacement condition of 3 mm.

The results indicate that increasing the number of layer boundaries in the hexagonal structure leads to higher radial stiffness and reaction force, while also tending to increase the maximum stress concentration. Based on both simulation and experimental results, the Type C spoke design demonstrates the most optimal compromise among stiffness, deformation, stress distribution, and vibrational characteristics compared to the other designs. These findings provide an important basis for the development and optimization of hexagonal-based non-pneumatic tire designs to enhance structural performance and reliability in vehicle applications.

Keywords: non-pneumatic tire (NPT), hexagonal, spoke, static analysis, finite element method, compression test