

INTISARI

Peningkatan kecepatan operasional kereta api pada implementasi Grafik Perjalanan Kereta Api 2025 (GAPEKA 2025) berpotensi meningkatkan respons dinamis kendaraan sehingga berisiko menyebabkan kontak antara rangka *bogie* dan *bolster* akibat berkurangnya *clearance* suspensi sekunder. Penelitian ini bertujuan menentukan kombinasi optimum kekakuan pegas (k) dan koefisien redaman (c) suspensi sekunder pada kereta penumpang dengan *bogie* agar *clearance* tetap berada pada rentang aman 25–50 mm selama operasi pada lintasan lengkung berjari-jari 150 m dengan ketidakaturan lintasan berdasarkan spektrum ERRI HI. Metode penelitian menggabungkan simulasi *multibody dynamics* menggunakan perangkat lunak Universal Mechanism dengan rancangan *Design of Experiments Full Factorial* tiga faktor tiga level (3×3) yang menghasilkan 27 skenario simulasi, kemudian dianalisis menggunakan *Analysis of Variance* pada taraf signifikansi 0,05. Hasil ANOVA menunjukkan kekakuan pegas sebagai faktor paling dominan ($F = 60,6994$, $P = 0,0001$), diikuti efek kuadratik kecepatan ($F = 82,5927$, $P = 0,0001$) dan koefisien redaman ($F = 7,3062$, $P = 0,0146$), dengan model regresi menjelaskan 90,9% variasi *clearance* minimum ($R^2 = 0,909$) tanpa interaksi antarfaktor yang signifikan. Kombinasi optimum global $k = 454.636$ N/m dan $c = 60.000$ Ns/m terbukti menjadi satu-satunya dari 27 skenario yang menjaga *clearance* dalam rentang aman pada seluruh kecepatan uji.

Kata Kunci : *Design of Experiments*, Dinamika Multibodi, Kendaraan Rel, Optimasi Parameter, Suspensi Sekunder.

ABSTRACT

The increase in railway operating speed under the 2025 Train Travel Chart (GAPEKA 2025) is expected to intensify the vehicle's dynamic response, thereby increasing the risk of contact between the bogie frame and bolster due to reduced secondary suspension clearance. This study aims to determine the optimum combination of secondary suspension spring stiffness (k) and damping coefficient (c) for a passenger railway vehicle equipped with a bogie to maintain the clearance within the safe range of 25–50 mm while operating on a 150 m radius curved track with ERRI HI track irregularity. The proposed methodology combines multibody dynamics simulation using Universal Mechanism software with a three-factor, three-level (3×3) full factorial Design of Experiments (DoE), resulting in 27 simulation scenarios that were subsequently analyzed using Analysis of Variance (ANOVA) at a significance level of 0.05. The ANOVA results identified spring stiffness as the most influential factor ($F = 60.6994$, $P = 0.0001$), followed by the quadratic effect of operating speed ($F = 82.5927$, $P = 0.0001$) and the damping coefficient ($F = 7.3062$, $P = 0.0146$). The regression model explained 90.9% of the variation in minimum clearance ($R^2 = 0.909$), with no significant interaction effects among the factors. The global optimum combination of $k = 454,636$ N/m and $c = 60,000$ N-s/m was the only configuration among the 27 simulation scenarios that maintained the clearance within the safe range at all tested operating speeds.

Keyword : Design of Experiments, Multibody Dynamics, Parameter Optimization, Railway Vehicle, Secondary Suspension.