

ABSTRAK

OPTIMASI KADAR TEMBAGA, KROMIUM, DAN TIMAH SEBAGAI SUBSTITUSI ANTIMON TERHADAP KEKERASAN DAN STRUKTUR MIKRO *DISC BRAKE FC200*

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Disc brake mobil umumnya diproduksi dari besi cor kelabu *grade FC200* dengan penambahan antimon (Sb) sebagai *pearlite stabilizer* untuk menjaga konsistensi kekerasan material. Pembatasan ekspor Sb oleh Tiongkok sejak September 2024 menyebabkan lonjakan harga dari USD 11.000–12.000 per ton menjadi lebih dari USD 35.000 per ton di Eropa pada 2025, menimbulkan risiko rantai pasok dan kenaikan biaya produksi bagi industri pengecoran otomotif. Penelitian ini bertujuan mengoptimasi kadar tembaga (Cu), kromium (Cr), dan timah (Sn) sebagai substitusi antimon serta mengevaluasi pengaruhnya terhadap kekerasan, struktur mikro, dan biaya paduan *disc brake FC200*.

Penelitian dilaksanakan pada skala produksi massal menggunakan metode *sand casting* berkapasitas *ladle* 1.200 kg. Lima skenario percobaan dirancang dengan variasi kadar Cu, Cr, dan Sn: percobaan I dengan Sb 0,035% sebagai *baseline*, dan percobaan III–V sebagai skenario substitusi tanpa Sb. Komposisi kimia diverifikasi menggunakan *Optical Emission Spectrometer*, kekerasan diuji dengan metode Brinell dan Vickers pada penampang melintang, serta struktur mikro dikarakterisasi menggunakan mikroskop optik mengacu standar ASTM A247.

Eliminasi Sb tanpa substitusi menyebabkan pertumbuhan grafit serpih mencapai rata-rata 200,26 μm , munculnya ferit bebas, dan penurunan kekerasan hingga 194 HV pada kondisi *overcooling*. Optimasi komposisi pada percobaan III dengan Cu 0,347% dan Cr 0,149% berhasil mengembalikan dominasi matriks perlit dan meningkatkan kekerasan kembali menjadi 215,4 HV, mendekati kondisi *baseline* Sb. Penambahan Sn 0,059% pada percobaan IV terbukti meningkatkan homogenitas distribusi kekerasan antar area penampang dengan nilai ΔHV sebesar 5,3 HV. Formulasi optimal diperoleh pada percobaan III dengan komposisi Cu 0,347%, Cr 0,147%, dan Sn 0,040%, yang mampu mempertahankan kualitas metalurgi setara kondisi penggunaan Sb sekaligus menghasilkan efisiensi biaya paduan sebesar 14,39% atau setara penghematan Rp140.123 per *ladle* dibandingkan skenario berbasis Sb.

Kata kunci: Antimon, besi cor kelabu, *disc brake FC200*, kekerasan, struktur mikro

ABSTRACT

OPTIMIZING COPPER, CHROMIUM, AND TIN CONTENT AS ANTIMONY SUBSTITUTES ON THE HARDNESS AND MICROSTRUCTURES OF FC200 DISC BRAKE

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Automotive disc brakes are commonly made from FC200 grey cast iron with antimony (Sb) addition as a pearlite stabilizer to maintain consistent hardness. China's export restrictions on Sb since September 2024 caused a price surge from USD 11,000–12,000 per ton to over USD 35,000 per ton in Europe in 2025, raising supply chain risks and production costs for the automotive casting industry. This study optimizes copper (Cu), chromium (Cr), and tin (Sn) content as antimony substitutes, evaluating their effects on hardness, microstructure, and alloying cost of FC200 disc brakes.

The study was conducted at full production scale using a sand casting method with a 1,200 kg ladle capacity. Five experimental scenarios were designed with varying Cu, Cr, and Sn contents, where Experiment I with 0.035% Sb served as the baseline condition and Experiments III–V as substitution scenarios without Sb. Chemical composition was verified using Optical Emission Spectrometry (OES), mechanical properties were evaluated through Brinell and Vickers hardness testing across the cross-sectional specimen, and microstructural characterization was performed using optical microscopy in accordance with ASTM A247.

Elimination of Sb without substitution caused flake graphite growth reaching an average of 200.26 μm , the appearance of free ferrite, and a hardness reduction to 194 HV under overcooling conditions. Composition optimization in Experiment III with 0.347% Cu and 0.149% Cr successfully restored pearlite matrix dominance and recovered hardness to 215.4 HV, approaching the Sb baseline. The addition of 0.059% Sn in Experiment IV improved hardness distribution homogeneity across the cross-sectional area with a ΔHV value of 5.3 HV. The optimal formulation was obtained in Experiment III with a composition of 0.347% Cu, 0.147% Cr, and 0.040% Sn, which maintained metallurgical quality equivalent to the Sb-based condition while achieving a 14.39% alloying cost efficiency, equivalent to Rp140,123 savings per ladle compared to the Sb-based scenario.

Keywords: *Antimony, disc brake FC200, grey cast iron, hardness, microstructures*