

ABSTRACT

This study investigates the condition of the C11 engine in the Load Haul Dump (LHD) R1600H unit, a critical machine used in the underground mining operations of the Deep Mill Level Zone (DMLZ) at PT Freeport Indonesia. Given the demanding workload and extreme environmental conditions, a predictive maintenance approach is essential to ensure operational reliability. The research integrates Scheduled Oil Sampling (SOS) and Failure Mode and Effect Analysis (FMEA) to detect early signs of wear, evaluate component degradation, and develop a targeted maintenance strategy. Laboratory analysis of oil samples collected during fieldwork at PT Trakindo Utama reveals elevated levels of key wear metals, particularly lead (Pb), iron (Fe), and aluminum (Al), indicating progressive wear in engine components. FMEA results identified engine knocking as the most critical failure mode based on the Risk Priority Number (RPN). Linear regression analysis on wear trends estimated the need to replace engine bearings at 10.021 hours of operation. Based on these findings, three primary recommendations were proposed: (1) implement a condition-based maintenance program with oil replacement every 250 hours, (2) conduct regular boroscope inspections to assess internal engine condition, and (3) perform a Scheduled major overhaul approaching 10,000 hours of operation. These strategies are expected to reduce the risk of severe engine failure, optimize machine availability, and enhance maintenance planning in underground mining environments. The study offers a data-driven framework for predictive maintenance and component lifespan estimation in heavy equipment operation.

Keywords: *Scheduled Oil Sampling (SOS), Failure Mode and Effect Analysis (FMEA), wear prediction, maintenance management, predictive maintenance*

INTISARI

Penelitian ini menganalisis kondisi *engine* C11 pada unit *Load Haul Dump* (LHD) R1600H, salah satu alat berat utama dalam operasi tambang bawah tanah *Deep Mill Level Zone* (DMLZ) PT Freeport Indonesia. Dengan mempertimbangkan beban kerja tinggi dan lingkungan kerja yang ekstrem, pendekatan pemeliharaan prediktif diperlukan untuk menjaga keandalan operasional alat. Studi ini mengintegrasikan metode *Scheduled Oil Sampling* (SOS) dan *Failure Mode and Effect Analysis* (FMEA) guna mendeteksi potensi keausan dini, mengevaluasi tingkat degradasi komponen, dan merancang strategi pemeliharaan yang lebih tepat sasaran. Analisis laboratorium terhadap sampel oli yang dikumpulkan selama praktik kerja lapangan di PT Trakindo Utama menunjukkan peningkatan kadar logam aus seperti timbal (Pb), besi (Fe), dan aluminium (Al) yang menandakan terjadinya keausan progresif pada komponen *engine*. Hasil analisis FMEA mengidentifikasi *engine knocking* sebagai mode kegagalan paling kritis berdasarkan perhitungan *Risk Priority Number* (RPN). Dengan analisis tren regresi linier, diperkirakan bahwa penggantian komponen bearing diperlukan pada jam operasi ke-10.021. Berdasarkan temuan ini, disusun tiga rekomendasi utama: (1) penerapan program *condition-based maintenance* dengan interval penggantian oli setiap 250 jam, (2) inspeksi boroscope berkala untuk memantau kondisi internal *engine*, dan (3) pelaksanaan major overhaul secara terencana menjelang 10.000 jam kerja. Strategi ini diharapkan mampu mengurangi risiko kerusakan berat, meningkatkan ketersediaan alat, dan mengoptimalkan efisiensi operasional di lingkungan tambang bawah tanah. Penelitian ini memberikan kerangka kerja berbasis data untuk penerapan pemeliharaan prediktif dan estimasi umur komponen pada alat berat.

Kata kunci: *Scheduled Oil Sampling (SOS), Failure Mode and Effect Analysis (FMEA), wear prediction, maintenance management, predictive maintenance*