ABSTRACT

This study aims to develop a heavy equipment maintenance strategy for a nickel mining system using an Integrated Maintenance Strategy (IMS) approach that integrates Reliability Centered Maintenance (RCM) and Age Replacement, while also considering Life Cycle Assessment (LCA). The research objects include Articulated Dump Truck (ADT), Excavator, and Dozer units operating in the stages of ore extraction, hauling, and material placement. The RCM analysis identified several critical components, namely tyres and rubber springs in ADT units; fuel filters and water separators in excavators; and track links and fuel filters in dozers. The implementation of preventive maintenance strategies demonstrated a significant improvement in system reliability through the reduction of component failure probabilities. The probability of failure for tyres and track links decreased from 46% to 6%, while the rubber spring failure probability decreased from 26% to 5%. For the excavator, the failure probability of fuel filters and water separators decreased from 24% to 15%, and the fuel filter in the dozer decreased from 33% to 13%. The integration of RCM and Age Replacement proved effective in reducing the risk of sudden failures and minimizing operational downtime. The LCA results indicate that the highest environmental impact category is Global Warming Potential (GWP100a) at 1.42 kg CO_2-eq/kg, with the hauling stage identified as the dominant contributor (hotspot). Furthermore, the energy transition analysis shows that the GWP value in the diesel-based scenario of 27.20 kg CO_2-eq/kg decreases to 14.00 kg CO_2-eq/kg in the hybrid system and 5.40 kg CO_2-eq/kg in the fully electric system powered by renewable energy. However, the GWP value increases to 46.00 kg CO_2-eq/kg when electricity is generated from coal-fired power plants. These findings confirm that optimizing maintenance strategies integrated with low-carbon energy transitions can simultaneously enhance system reliability and significantly reduce environmental impacts.

Keywords: *Integrated Maintenance Strategy (IMS), Life Cycle Assessment (LCA), Energy Transition, Electrification, Nickel Mining*

INTISARI

Penelitian ini bertujuan mengembangkan strategi pemeliharaan alat berat pada sistem pertambangan nikel melalui pendekatan *Integrated Maintenance Strategy* (IMS) yang mengintegrasikan *Reliability Centered Maintenance* (RCM) dan *Age Replacement* serta mempertimbangkan *Life Cycle Assessment* (LCA). Objek penelitian meliputi unit *Articulated Dump Truck* (ADT), *Excavator*, dan *Dozer* pada tahapan *ore extraction*, *hauling*, dan *material placement*. Hasil RCM mengidentifikasi komponen kritis, yaitu *tyre* dan *rubber spring* pada ADT; *Fuel Filter* dan *water separator* pada *Excavator*; serta *track link* dan *Fuel Filter* pada *Dozer*. Penerapan strategi pemeliharaan *preventive* menunjukkan peningkatan keandalan yang signifikan melalui penurunan probabilitas kegagalan komponen. Probabilitas kegagalan *tyre* dan *track link* menurun dari 46% menjadi 6%. Komponen *rubber spring* menurun dari 26% menjadi 5%, *Fuel Filter* dan *water separator Excavator* dari 24% menjadi 15%, serta *Fuel Filter Dozer* dari 33% menjadi 13% . Integrasi RCM dan *Age Replacement* terbukti efektif dalam menekan risiko kegagalan mendadak dan mengurangi *downtime* operasional. Hasil LCA menunjukkan bahwa kategori dampak tertinggi adalah *Global Warming Potential* (GWP100a) sebesar 1,42 kg CO_2-eq/kg, dengan tahap *hauling* sebagai kontributor dominan (*hotspot*). Analisis transisi energi menunjukkan bahwa nilai GWP pada skenario diesel sebesar 27,20 kg CO_2-eq/kg menurun menjadi 14,00 kg CO_2-eq/kg pada sistem *hybrid* dan 5,40 kg CO_2-eq/kg pada sistem *fully electric* berbasis energi terbarukan, namun meningkat menjadi 46,00 kg CO_2-eq/kg apabila listrik bersumber dari PLTU batu bara. Hasil ini menegaskan bahwa optimasi pemeliharaan yang terintegrasi dengan transisi energi rendah karbon mampu meningkatkan keandalan sekaligus menurunkan dampak lingkungan secara signifikan.

Kata kunci: *Integrated Maintenance Strategy* (IMS), *Life Cycle Assesment* (LCA), Transisi Energi, Elektrifikasi, Pertambangan Nikel