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Root cause failure analysis of a high-pressure diesel fuel line: Evidence of cavitation erosion–induced leakage

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ABSTRACT

High-pressure fuel delivery systems are critical to the reliability and safety of heavy-duty diesel engines. This study investigates the root cause failure of a high-pressure diesel fuel line tube from a Caterpillar 3516B diesel engine used for power generation, which experienced leakage after 8,922 h of service. A systematic investigation was conducted, including fuel quality assessment, metallographic examination, and advanced surface characterization techniques. Fuel analysis confirmed that all parameters were within acceptable limits, ruling out fuel contamination as the primary factor. Metallurgical evaluation showed that the tube material was low-carbon steel with a typical ferritic–pearlitic microstructure and nominal chemical composition, with no evidence of microstructural degradation or manufacturing defects. In contrast, scanning electron microscopy revealed severe cavitation erosion on the internal surface, characterized by deep pits, undercut craters and material loss. Energy-dispersive X-ray spectroscopy further identified substantial carbonaceous deposits on the eroded regions, indicative of fuel decomposition under unstable hydrodynamic conditions. The combined evidence demonstrates that the leakage resulted from cavitation erosion–induced wall thinning driven by pressure fluctuations, high local fuel velocity and flow instability, rather than fatigue or material-related failures. The findings highlight cavitation erosion as a critical and often overlooked failure mechanism in high-pressure diesel fuel lines operating under severe service conditions.

1. Introduction

The reliability and safety of diesel engine generator sets are critically dependent on the integrity of their fuel delivery systems. In high-powered applications, any malfunction in fuel line components can result in significant performance degradation and safety hazards. High-pressure fuel pipes which serve as key components linking injection pumps to injectors, are regularly subjected to intense cyclic pressures. These dynamic loads make them prone to fatigue failure, particularly in areas experiencing high tangential

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