

INTISARI

ANALISIS KERUSAKAN ROD CYLINDER ARM HASIL REMANUKTUR PADA EXCAVATOR DI PT XYZ

Rod cylinder arm excavator CAT 6015 hasil remanufaktur oleh PT XYZ mengalami patah prematur di ujung rod setelah sekitar 200 jam pemakaian. Rod terbuat dari baja paduan VCL 140 (ekivalen AISI 4140) kondisi *annealed* dengan *hardfacing* pada ujung rod, dan telah melalui *preheat*, *post-weld heat treatment* (PWHT), serta uji tak rusak (UT dan *dye penetrant*) sebelum pengiriman. Penelitian ini bertujuan menentukan mekanisme dan akar penyebab kegagalan melalui inspeksi visual dan makroskopis, uji kekerasan Vickers, uji impact Charpy, metalografi, serta fraktografi SEM dan analisis EDX; data sekunder uji tarik digunakan sebagai pembandingan terhadap spesifikasi OEM. Permukaan patahan relatif datar tanpa *necking*, dengan pola chevron yang mengarah ke titik asal pada batas antarmuka *hardfacing*–HAZ. Kekerasan rata-rata zona *hardfacing*, transisi (HAZ), dan logam dasar berturut-turut 546,9; 398,8 (sebaran 296,6–556,7); dan 278,0 HV. Energi serap impact Charpy sebesar 12,2–19,2 J (rata-rata 15,1 J), jauh di bawah acuan AISI 4140 *annealed* (~54 J). Struktur mikro logam dasar berupa ferrite-pearlite. Fraktografi SEM menunjukkan cleavage dan quasi-cleavage pada ketiga zona, dengan jalur retak mengikuti antarmuka *hardfacing*–HAZ dan tanpa striasi fatigue pada area yang diamati. Analisis EDX pada logam dasar menunjukkan Cr 0,87–1,02%, sesuai rentang AISI 4140, sedangkan hasil pada *hardfacing* kurang representatif. Kegagalan disimpulkan sebagai patah getas (brittle fracture) yang diinisiasi di antarmuka *hardfacing*–HAZ dan bersifat multifaktorial: ketangguhan logam dasar kondisi *annealed* yang rendah, PWHT yang diindikasikan belum cukup meng-temper martensit pada HAZ, serta beban kejut akibat salah operasi di lapangan. Rekomendasi meliputi pengetatan prosedur PWHT dengan kriteria kekerasan HAZ di bawah 350 HV, penambahan uji partikel magnetik, dan pelatihan operator.

Kata kunci: analisis kegagalan, rod silinder, VCL 140/AISI 4140, *hardfacing*, patah getas.

ABSTRACT

FAILURE ANALYSIS OF A REMANUFACTURED ARM CYLINDER ROD IN AN EXCAVATOR AT PT XYZ

The remanufactured arm cylinder rod of a CAT 6015 excavator produced by PT XYZ fractured prematurely at the rod end after approximately 200 operating hours. The rod was made of VCL 140 alloy steel (equivalent to AISI 4140) in the annealed condition with hardfacing at the rod end, and had undergone preheating, post-weld heat treatment (PWHT), and non-destructive testing (ultrasonic and dye penetrant) before delivery. This study aimed to determine the failure mechanism and root cause through visual and macroscopic inspection, Vickers hardness testing, Charpy impact testing, metallography, and fractography by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDX); secondary tensile data were used for comparison with OEM specifications. The fracture surface was relatively flat without necking, with chevron marks pointing to an origin at the hardfacing–HAZ interface. Average hardness of the hardfacing, transition (HAZ), and base metal zones was 546.9, 398.8 (range 296.6–556.7), and 278.0 HV, respectively. Charpy absorbed energy was 12.2–19.2 J (mean 15.1 J), far below the annealed AISI 4140 reference (~54 J). The base metal microstructure consisted of ferrite–pearlite. SEM fractography showed cleavage and quasi-cleavage in all three zones, with the crack path following the hardfacing–HAZ interface and no fatigue striations in the observed areas. EDX on the base metal gave Cr of 0.87–1.02 wt%, within the AISI 4140 range, whereas the hardfacing measurement was unrepresentative. The failure is concluded to be a brittle fracture initiated at the hardfacing–HAZ interface and is multifactorial: low toughness of the annealed base metal, PWHT indicated to be insufficient to temper martensite in the HAZ, and impact loading from field misoperation. Recommendations include a stricter PWHT procedure with a HAZ hardness criterion below 350 HV, added magnetic particle testing, and operator training.

Keywords: *failure analysis, cylinder rod, VCL 140/AISI 4140, hardfacing, brittle fracture.*