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ASTM A743 CA6NM Martensitic stainless steel pressure vessel failure due to stress corrosion cracking

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This work investigated a premature failure of a pressure vessel manufactured in A743 CA6NM martensitic stainless steel. The pressure vessel operated with a NaCl solution (165,000 ppm) in a CO₂ atmosphere at constant temperature and pressure, 90°C and 60 MPa pressure. After 11 days of operation, the equipment failed. Leak test, liquid penetrant examination, and magnetic particle tests were carried out to investigate the size and position of the cracks, as well as the extent of damage along the pressure vessel. Several techniques were used to characterize the failure and the material: optical microscopy (OM), scanning electron microscopy (SEM), quantitative chemical analysis by optical emission spectroscopy, semi-quantitative chemical analysis by energy dispersive spectroscopy (EDS), and Vickers microhardness (HV). The chemical composition was in accordance with the material's specifications. As expected for the A743 CA6NM, the microstructural characterization shows the martensite phase without carbides at grain boundaries. Microhardness tests were conducted in regions far from and close to the bottom of the pressure vessel, a region with more crack incidence. The results confirmed that the heat treatment procedure was carried out satisfactorily. A microhardness of 489 ± 6 HV was obtained in a region close to the cracks found, and a microhardness value of 475 ± 13 HV was obtained in a region far from the failure. Considering the margin of error, the microhardness test demonstrated the regularity of hardness of martensitic stainless steel. Observation by microscopy revealed several cracks, which cross the entire thickness of the pressure vessel. The results showed several branched transgranular cracks, typically associated with stress corrosion cracks. The cracks were more concentrated in the bottom of the pressure vessel, the region that had presented a worse surface finish. Residual stress analysis was not performed. The exposure of the material to the acidic NaCl solution generated the nucleation of the crack in the internal region. The surface finishing was poor at the bottom of the pressure vessel, the fluid was rich in Cl (free chlorine ions in the solution), and the pressure vessel had an internal pressure; the synergy of those parameters favored a rapid stress corrosion process.