Case Study: Fitness-for-Service Assessment of Welded Penstock

Overview

Genesis Energy Ltd, NZ operates three hydropower stations at Waikaremoana Lake that were built between 1927 and 1948. The structural integrity of the penstocks had been of concern to them for some time. Due to an overload incident in 1982, a failure occurred at the Tuai G3 welded penstock. The outcome of the failure investigation concluded that the welds in the penstocks were full of original fabrication defects and the materials fracture toughness was low. The conclusions prompted a range of assessment work to be carried out on the penstocks.

The fracture toughness was determined with charpy tests, and the critical flaw dimensions were calculated in accordance to BS7910:1999; a FFS procedure analogous to section 9 of the API 579/ASME FFS-1. This assessment was conducted using Quest Integrity's validated and commercially available fitness-for-service software SignalFFS™.

Welded Penstocks

The three different regions where residual stresses are defined for the defect assessment.

Penstock located at Tuai, New Zealand. On the right: two riveted penstocks, and on the left: one welded penstock.

Example of weld cruciform

Surface breaking in weld cap (55mm/2 inches long and 9mm/.35 inches deep). The ends of the crack are narrowed.
Results

Charpy test and defect assessment of the Piripaua penstock was carried out to determine the maximum tolerable flaw sizes for the avoidance of failure during an overloading situation.

- Using well validated codes (BS7910:1999) and Quest Integrity’s commercially available fitness-for-service software SignalFFS™, critical defect sizes were determined. It was concluded that the acceptable defects sizes were larger than originally thought. The maximum defects known from previous inspections were shown to be acceptable during an over pressure incident. The results from the defect assessment can be used as criteria for immediate evaluation of the fitness for service during an inspection.

- The assessment shows that the maximum length of a through thickness flaw was determined to be between 104-115mm/4-4.5 inches depending on position along the penstock, except for the most upper section where the acceptable length is in excess of 600mm/23.5 inches.

- The maximum flaw height of a long surface breaking flaw (1500mm/5 ft. long) which is more than 160mm/6 inches away from the cruciform is between 4 and 6.5mm/.15 and .25 inches depending on the position along the penstock.

- At a distance 160mm/6 inches away from the cruciform surface breaking flaw heights, between 8-11mm/.31-.43 inches can be accepted provided the length is less than 100mm/4 inches.

- For a continuous long embedded flaw which is located 160mm/6 inches away from the cruciform, the maximum height for a 2mm/.078 inches ligament is between 6.5mm/.25 inches and 7.7mm/.30 inches. Along the cruciform surface breaking flaws, between 8mm and 9.5mm/.31-.37 inches deep can be accepted, as long as they are confined to the width of the cruciform weld (assumed to be 40mm/1.57 inches).

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