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Permanent effect of a cryogenic spill on fracture properties of structural steels

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Fracture analysis of a standard construction steel ship deck, which had been exposed to a liquid nitrogen spill, showed that the brittle fracture started at a flaw in the weld as a consequence of low-temperature embrittlement and thermal stresses experienced by the material. In the present study, the permanent effect of a cryogenic spill on the fracture properties of carbon steels has been investigated.
Charpy V-notch impact testing was carried out at 0 C using specimens, from the ship deck material. The average impact energy appeared to be below requirements only for transverse specimens. No pre-existing damage was found when examining the fracture surfaces and cross sections in the SEM.
Specimens of the ship deck material and a DOMEX S355 carbon steel were tensile tested in liquid nitrogen. Both steels showed a large increase in yield- and fracture strength and a large increase in the Lüders strain compared to the room temperature behavior. A cryogenic spill was simulated by applying a constant tensile force to the specimens for 10 min, at -196 C. Subsequent tensile tests at room temperature showed no significant effect on the tensile behavior of the specimens.
A small amount of microcracks were found after holding a DOMEX S355 specimen at a constant force below the yield point. In a ship deck material tensile tested to fracture in liquid nitrogen, cracks associated with elongated MnS inclusions were found through the whole test region. These cracks probably formed as a result of the inclusions having a higher thermal contraction rate than the steel, causing decohesion at the inclusion-matrix interface on cooling. Simultaneous deformation may have caused formation of cracks. Both the microcracks and sulphide related damage may give permanently reduced impact energy after a cryogenic exposure.

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