STUDIES ON WELDABILITY OF THERMOMECHANICALLY CONTROL PROCESSED VANADIUM-TITANIUM CONTAINING HSLA STEEL

ABSTRACT

Microalloyed steels are the group of high strength low alloy (HSLA) steels which are designed to provide better strength and toughness without impairing weldability. These steels are often used as better alternatives for quenched and tempered steels due to their excellent combination of these properties. The beneficial properties in these steels are achieved by careful control of composition and by adopting suitably controlled thermomechanical processing. Improved weldability is achieved by maintaining carbon at a low level. To compensate the loss of strength due to low carbon, small amounts of alloying elements, such as niobium, vanadium, titanium, aluminium and nitrogen are added. Applications of microalloyed HSLA steels include oil and gas pipelines, heavy-duty highway and off-road vehicles, construction and farm machinery, industrial equipments, storage tanks, mine and railroad cars, barges and dredges, snowmobiles, lawn mowers, and passenger car components. Bridges, offshore structures, power transmission towers, light poles, and building beams and panels are additional uses of these steels. In all these applications, welding plays a key role in the fabrication. Hence, weldability aspects of these steels are to be carefully examined and evaluated so that the structural integrity and thereby the reliability is fully ensured.

One of the major problems associated with welding of microalloyed HSLA steels is loss in heat affected zone (HAZ) toughness at high heat inputs and most of the previous investigations were confined to this study only. There is only a limited published data available on weld cracking of these steels. This could be due to the reason that, the weldability of these steels is generally believed to be excellent

due to their controlled chemistry. On the other hand, the limited literature available on weld cracking of low alloy steels are mainly restricted to those groups of steels where strengthening is achieved through carbon and alloy dominated mechanisms. Hot cracking and hydrogen induced cracking (HIC) are the two common weld cracking problems associated with the welding of high strength steels.

The material taken up for the present research is an indigenously developed new HSLA steel (YS 570 MPa; UTS 780 MPa) with a nominal composition of 0.18%C-1.6%Mn-0.18%V-0.017%Ti. This steel finds applications in truck frames, brackets, crane booms, rail cars and ATM chests. Welding is an important processing step in all these applications. From the chemical composition, assessment of susceptibility for hot cracking of the chosen steel using the available empirical relations shows that the steel is prone for hot cracking. The microalloyed HSLA steels provide adequate resistance to hydrogen induced cracking at normal yield strength levels. But, these steels are prone for hydrogen induced cracking especially when the yield strength levels are high. Hence, evaluation of the resistance of the chosen steel for both hot cracking and hydrogen induced cracking becomes necessary. The present research work was aimed at the evaluation of susceptibility of the chosen steel for hot cracking and hydrogen induced cracking.

Hot cracking susceptibility was evaluated by using varestraint test. The evaluation was done by varying augmented strain and welding current levels taking maximum crack length as evaluation criteria. The results showed that the steel is not sensitive to hot cracking. Cracks were observed only at higher levels of strain corresponding to the stresses beyond the yield point of the steel.

Susceptibility to HIC was evaluated by means of implant testing. Tests were conducted using shielded metal arc welding (SMAW) and gas metal arc welding (GMAW) processes at varying welding conditions. The major part of the work was carried out with GMAW process. SMAW process has higher hydrogen potential compared to GMAW process. Tests using SMAW process were carried out only at limited welding conditions.

HIC occurs due to the combined effect of tensile residual stresses, diffusible hydrogen and certain susceptible microstructures. Residual stresses in the weldment at different welding conditions were determined by using X-ray diffraction technique. Diffusible hydrogen content of the SMAW and GMAW electrodes was determined by using mercury displacement method. The microstructures of the weldment were characterized through optical microscopy. The mixture of phases found in the HAZ that are indistinguishable by optical microscopy was identified by using transmission electron microscopy (TEM). Hardness survey was carried out using Vicker's microhardness tester. The morphology and composition of microalloy precipitates found in the unaffected and heat affected zone of the base metal were characterized through TEM with energy dispersive spectrometric (EDS) analysis.

The results of implant tests and characterization tests indicated that the steel is prone for HIC in the coarse grained heat affected zone (CGHAZ) and the HIC can be completely eliminated by increasing heat inputs and/or preheat temperatures. Implant fracture surfaces were characterized through scanning electron microscopy (SEM) to identify the failure mechanism. Based on the results of implant tests, a 'window of safe welding parameters' was suggested that can provide 'safe welding' conditions for the chosen steel using GMAW process.