# ABSTRACT

The current work investigates the influence of the microstructure on the tensile, corrosion, and formability behaviour of a novel nickel-modified austenitic-based medium manganese advanced high strength steel (AHSS). The alloy development steps include casting, hot-forging, hot-rolling and annealing (at 973 K, 1173 K and 1373 K) to comprehend the structure-property relationship. Firstly, the microstructural evolution and tensile behavior of the developed steel has been studied in hot-rolled (HR) and annealed specimens (HR-973 K, HR-1173 K and HR-1373 K). The microstructure of the HR and HR-973 K specimens comprise BCC and FCC phases, along with B2 (NiAl) and κ-carbide precipitates. However, in HR-1173 K specimen, the κ-carbide dissolves, promoting the evolution of B2 precipitates along with BCC and FCC phases. Further, in the HR-1373 K, the dissolution of both precipitates occurs, stabilizing both the FCC and BCC phases. Among all conditions, the HR specimen demonstrates superior strength-ductility synergy (UTS×TE ~ 63910 MPa%) with exceptional ductility (TE ~ 70 ± 1.1%). The enhanced ductility of the HR specimen is attributed to its optimal grain size, evenly dispersed nano-sized B2 precipitates, low grain boundary (GB) B2 fraction, higher dislocation density, and predominant twinning-induced plasticity (TWIP) effect. In contrast, the HR-1173 K specimen shows the highest tensile strength (UTS ~ 1103 ± 21 MPa because of increased B2 precipitation and twin-assisted grain refinement. However, the HR-1373 K specimen exhibits the lowest strength because of reduced FCC fraction, increased grain size, precipitate dissolution, and a diminished TWIP effect. Based on excellent tensile behavior of the HR, HR-973 K and HR-1173 K specimens, their corrosion performance was systematically evaluated in simulated marine conditions using a 3.5 wt.% NaCl solution. The dominant corrosion mechanism identified across all these specimens is micro-galvanic interaction arising from volta potential differences between the constituent phases. The superior corrosion performance of the HR specimen is mainly attributed to the minimal volta potential difference between the BCC and FCC phases, which suppressed localized galvanic activity. In contrast, the HR-973 K specimen displays the most severe corrosion, primarily due to the pronounced volta potential difference between the FCC and BCC phases, resulting in intensified micro-galvanic interactions. The enhanced oxide layer stability of the HR specimen corroborates its superior corrosion performance as compared to other specimens, which is consistent with the findings that are observed in the potentiodynamic polarization, electrochemical impedance spectroscopy (EIS), and immersion test results. So, based on the superior tensile and corrosion performance of the HR specimen, a detailed investigation on the stretch forming behavior is carried out. For the formability study, the HR specimen is renamed as as-received (AR) specimen due to minor difference in thickness reduction during hot-forging and hot-rolling operations. The AR specimen is subjected to stretch forming tests to achieve uniaxial, plane strain and biaxial strain paths, allowing for the construction of a forming limit diagram (FLD). An excellent formability with a formability index, $FLD_0$ of 0.39 has been estimated. A higher magnitude of effective plastic strain is observed in the biaxial specimen, resulting in finer grains and a greater fraction of sub-grain boundaries, 2º-5º (73.5 ± 2.3 %) relative to uniaxial (59.6 ± 1.9 %) and plane strain (52.2 ± 1.3 %) specimens. Further, the effect of varying strain paths on the formation of deformation twins and void characteristics has been systematically studied, and the underlying fracture mechanism has subsequently been elucidated. The biaxial specimen exhibited higher limiting dome height values (LDH ~ 19 mm), which could be related to a slower crack propagation rate owing to the development of finer grains and nano-twin structures. Finally, the microstructural and texture evolution under uniaxial, plane strain and biaxial strain paths has been systematically investigated. Under uniaxial condition, pronounced Copper {112}<111>, Brass {110}<112>, and S {123}<634> texture components are developed, while plane strain condition exhibits a stronger Goss {110}<001>. In contrast, the biaxial deformation exhibits a pronounced intensification of Brass and Goss components. Further, the visco-plastic self-consistent (VPSC) polycrystalline model is employed to predict texture development and slip/twin system activity under multiple strain paths. The VPSC simulation demonstrated that the slip system activity increases while twinning activity diminishes at later stages of deformation, irrespective of strain paths. Finally, a comprehensive investigation of the Taylor factor (M) has been conducted to understand its spatial distribution correlation with surface roughening behavior across three strain paths. The plane strain specimen, characterized by a wider Taylor factor distribution (M ~ 2.01–4.29) and limited slip system activation, exhibits greater hardness mismatches among neighboring grains, resulting in the highest surface roughness (Ra = 1.27 ± 0.22 μm) as compared to the uniaxial (Ra = 0.57 ± 0.07 μm) and biaxial (Ra = 0.93 ± 0.06 μm) specimens.

***Keywords*****:** Ni-modified AHSS; B2 (NiAl) precipitates; Tensile properties; Corrosion resistance; Marine environment; Micro-galvanic effect; Stretch forming; Strain paths; Failure mechanism; Crystallographic texture; VPSC simulation; Taylor factor; Surface roughness.